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AIRPORT CRASH/FIRE/RESCUE (CFR) SERVICE COST AND BENEFIT ANALYS--ETC(U)
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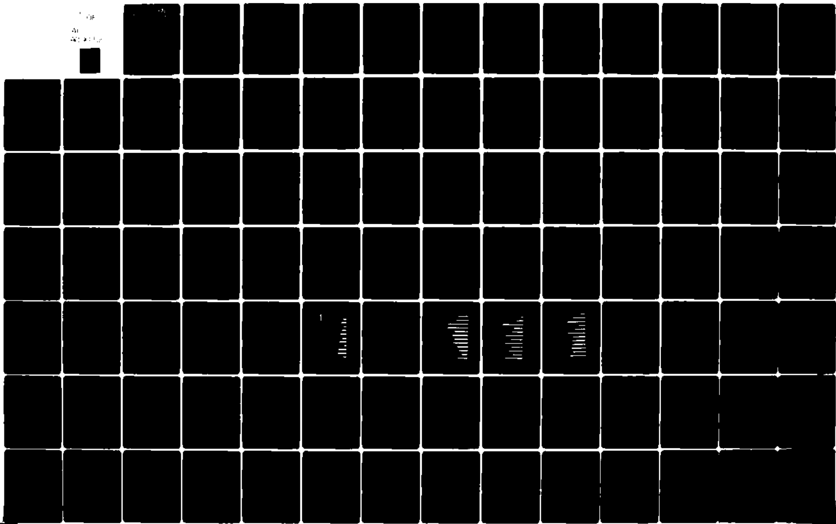

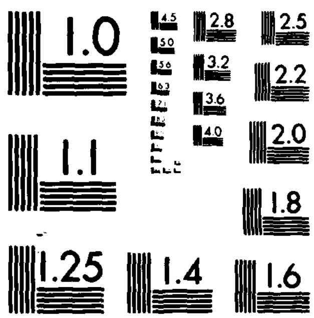

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(10) LEVEL II

US Department of Transportation
Federal Aviation Administration

Airport Crash/Fire/Rescue (CFR) Service Cost and Benefit Analysis
Volume I: Text

Office of Airport Standards
Washington, D.C. 20591

AD A090726

DTIC ELECTE OCT 23 1980 S D F

DOT/FAA/AS/80-2

July 1980

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80 10 21 050

Technical Report Documentation Pag

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
(14) FAA-AS-80-2-Vol-1	AD-A090 726	

4. Title and Subtitle	5. Report Date
(6) Airport Crash/Fire/Rescue (CFR) Service Cost and Benefit Analysis. Volume I. Text.	(11) Jul 1980
	6. Performing Organization Code
	8. Performing Organization Report No. (12) 141
7. Author(s)	
9. Performing Organization Name and Address U. S. Department of Transportation Federal Aviation Administration 800 Independence Ave. S. W. Washington, D. C. 20591	10. Work Unit No. (TRAIS) 11. Contract or Grant No. 13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address U. S. Department of Transportation Federal Aviation Administration Office of Airport Standards Washington, D. C. 20591	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

17. Key Words	18. Distribution Statement
	This document is available to the public through the National Technical Information Service, Springfield, Va. 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	142	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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ACKNOWLEDGEMENTS

The data collected in the course of this study have been provided by a variety of sources within the aviation community. We are grateful to these sources, which include personnel at FAA Headquarters, Regional Offices, and Airport District Offices, airport operators and executives, fire chiefs and firefighters, pilots, flight attendants, and members of the staff of the organizations listed on page 1-5 of this report. Their cooperation and respective concerns for various CFR issues indicate firm support for achieving aviation safety through effective planning and prudent distribution of limited resources.

The completion of this analysis of CFR costs and benefits was guided by Mr. Jose Roman, Jr., of the FAA's Office of Airport Standards. His suggestions and contributions to the final report are very much appreciated.

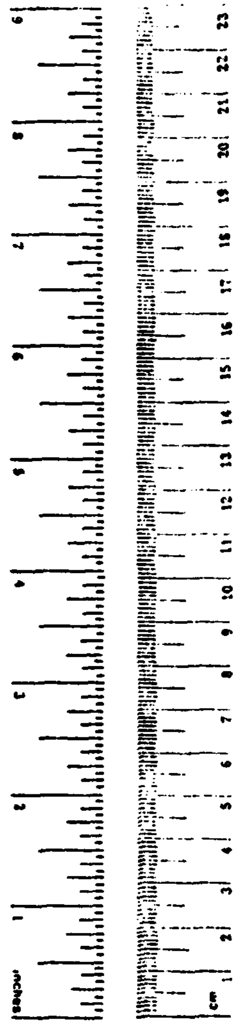
Mr. Edgar Williams, now with FAA's Office of Airport Planning and Programming, devised the plan for accomplishing the objectives of the study and participated in the collection and analysis of the data, as well as in the presentation of interim results. We are grateful for his support and encouragement which have been essential to achieving the study's goals.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

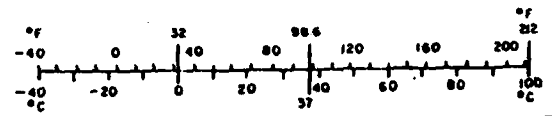
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

Primarily to improve the chances of human survival in the event of an aircraft accident at an airport, airport authorities throughout the country maintain a crash/fire/rescue (CFR) service. Such a service has, in fact, since 1972 been required of certain airports under Federal Aviation Regulation Part 139, Certification and Operations: Land Airports Serving CAB-Certificated Air Carriers. To assist the Federal Aviation Administration in its evaluation of airport safety programs, HH Aerospace Design Company, Inc., has prepared an analysis of the costs and benefits of CFR services at all public use airports throughout the country. This analysis does not attempt to assess the impact of Part 139 requirement on aviation safety, but simply presents the data required by the FAA to consider future policy regarding CFR in the presence of an everchanging aviation environment.

Both cost and benefit data were obtained from various records available in Washington and in the FAA's Regional Offices, as well as from visits to a number of airports throughout the country. Information on the number of CFR vehicles and personnel at each airport was obtained primarily from Airport Operations Manuals and Operations Specifications, which are required to be filed with the various regional offices of the FAA by Part 139 in the case of most airports serving CAB-certificated air carriers. Other data used in estimating CFR cost (e.g. salary levels)

were obtained in the course of interviews with airport authorities and CFR personnel.

Benefit data were determined from aircraft accident records, primarily those of the National Transportation Safety Board (NTSB), and from inspection of airport CFR logs at various locations throughout the country. Crash benefits were assessed with the assistance and concurrence of a variety of organizations concerned with aviation safety including the following:

Air Line Pilots Association
Air Transport Association of America
Airport Operators Council International, Inc.
American Association of Airport Executives
Association of Flight Attendants
National Air Transportation Association
National Association of State Aviation Officials
National Business Aircraft Association, Inc.

The participation and support of these groups in the collection of data and provision of various viewpoints of CFR services have enabled the study to develop a broad base of information from which the FAA can make future policy decisions.

All dollar values discussed in the analysis and in this summary are stated in April 1979 dollars. Costs and benefits are considered for all public use airports under United States jurisdiction with the exception of Alaskan airports, which have a

number of unusual operating conditions, and those airports where CFR services are provided by the military. The latter are excluded because at such facilities, which include Air Force bases and airports served by the Air National Guard, CFR services would be provided even in the absence of non-military traffic. Such a condition is not relevant in the context of this study, which concerns public aviation.

Cost data were developed for each of four categories: manpower, CFR vehicles, buildings, and equipment. These costs are summarized in Table ES-1, which breaks the costs down according to airport CFR index. CFR service is provided at an estimated 100 airports without operating certificates, primarily busy general aviation airports, but the total cost of CFR at these airports is just 1.2% of the total estimated annual cost of $115.3 million. Index C, D, and E airports combined account for 73.5% of the total annual cost of CFR. 79.6% of the total cost of CFR nationally is manpower, including personnel benefits, while 11% lies in vehicle expenditures, 6.2% for buildings, and 3.2% for equipment.

Benefits fall into three major categories: the prevention of human loss (death or injury), the prevention of property loss (primarily aircraft hull damage), and non-crash service benefits such as emergency stand-bys, fuel spill washdowns, medical responses in terminal buildings, and structural fires at the airport. An examination of 628 air carrier accidents over the

Table ES-1: Summary of Annual CFR Costs by Airport Index and Expenditure Category in Fiscal Year 1979 ($K)

	Manpower	Vehicles	Buildings	Equipment	Total by Index
Index E (17)	18,374	1,905	1,240	849	22,368 (19.4%)
Index D (26)	16,327	2,044	1,256	686	20,313 (17.6%)
Index C (91)	34,187	3,803	2,840	1,281	42,111 (36.5%)
Index B (73)	9,601	1,701	736	373	12,411 (10.8%)
Index AA (83)	5,107	1,418	338	195	7,058 (6.1%)
Index A (152)	5,890	1,254	456	225	7,825 (6.8%)
Limited Certificate (36)	1,294	373	126	49	1,842 (1.6%)
No Certificate (100)	1,021	133	200	39	1,393 (1.2%)
Total by Category	91,801 (79.6%)	12,631 (11.0%)	7,192 (6.2%)	3,697 (3.2%)	115,321

N.B. The numbers in parentheses below each index show the number of airports in that index. The total number of airports is 578.

period 1966-1978 showed that 133 deaths and 40 injuries were prevented by CFR. Of this total, 98 lives were saved and 19 injuries prevented in the Continental DC-10 accident at Los Angeles International Airport on March 1, 1978. Using imputed values for human life and injury of $430,000 and $64,000, respectively—values currently accepted in other studies performed by the FAA—one arrives at the dollar values for lives and injuries saved as summarized in Table ES-2 as a function of airport index. In accordance with a methodology for assessing the "psychological" benefit of CFR which is discussed in detail in the report, the total psychological benefit is assumed equal to the actual death and injury benefits obtained over the period but distributed over the period according to passenger enplanements. The resulting "human benefit," the sum of actual life/injury and psychological benefits, is presented in Table ES-3. This benefit averages nearly $10 million per year over the period examined.

The value of aircraft hulls saved as determined from examination of the same air carrier accident records is summarized in Table ES-4. The resulting average annual benefit for this category over the period 1966-1978 is $214.45 million.

Commuter and air taxi accidents were determined to contribute an annual average benefit of $0.2 million in lives saved and injuries prevented (0.5 lives per year), and $1.0 million per year in aircraft damage prevented. General aviation death/injury benefits

Table ES-2: Benefits Provided by CFR in Preventing
Air Carrier Deaths and Injuries
Broken Down by Year and Airport Index
(Millions of Dollars)

	Airport Index							
Year	L	A	AA	B	C	D	E	Total
1966	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0
1971	0	0	0.430	0	0	0	0	0.430
1972	0	0	0	0	0	0	0.256	0.256
1973	0	0	0	0	2.150	0	0	2.150
1974	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	[illegible].558	13.558
1976	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	43.356	43.356
Total	0	0	0.430	0	2.150	0	57.170	59.750

Table ES-3: Human Benefits Provided by CFR for Air Carriers
Broken Down by Year and Airport Index
(Millions of Dollars)

Year	L	A	AA	B	C	D	E	Total
	Airport Index							
1966	0.001	0.017	0.021	0.087	0.581	0.851	1.149	2.707
1967	0.001	0.021	0.026	0.106	0.702	1.029	1.389	3.274
1968	0.001	0.023	0.029	0.120	0.798	1.169	1.580	3.722
1969	0.002	0.025	0.031	0.128	0.851	1.246	1.684	3.967
1970	0.002	0.027	0.034	0.137	0.912	1.337	1.805	4.254
1971	0.002	0.027	0.464	0.139	0.925	1.355	1.831	4.744
1972	0.002	0.030	0.037	0.151	1.005	1.472	2.244	4.940
1973	0.002	0.032	0.040	0.162	3.225	1.575	2.128	7.163
1974	0.002	0.032	0.041	0.166	1.101	1.613	2.178	5.133
1975	0.002	0.032	0.040	0.163	1.084	1.588	15.703	18.613
1976	0.002	0.035	0.043	0.177	1.178	1.725	2.330	5.491
1977	0.002	0.037	0.047	0.191	1.270	1.860	2.513	5.921
1978	0.002	0.039	0.049	0.201	1.333	1.952	45.993	49.570
Total	0.023	0.377	0.902	1.928	14.965	18.772	82.527	119.500

Note: Components may not add to totals due to rounding.

Table ES-4: Value of Aircraft Hulls Saved in Air Carrier Accidents by CFR, 1966-1978 (Millions of Dollars)

	Airport Index							
Year	L	A	AA	B	C	D	E	Total
1966					1.60		2.40	4.00
1967					0.30	3.05	3.60	6.95
1968						0.50	0.40	0.90
1969		1.20			1.20			2.40
1970					4.00	1.50	3.80	9.30
1971							3.60	3.60
1972						17.70	44.05	61.75
1973					12.90	9.00	40.85	62.75
1974						7.60		7.60
1975					7.60		28.00	35.60
1976					0.40	8.70		9.10
1977								0.00
1978							10.50	10.50
Total	0.00	1.20	0.00	0.00	28.00	48.05	137.20	214.45

are negligible, while aircraft damage benefits are estimated to be $0.1 million per year. The psychological benefit is again assumed to be equal to the life/injury benefit. These commuter and general aviation benefit estimates are included in the final summary of CFR benefits.

The non-crash benefits were determined primarily from inspection of CFR logs and tabulation of activities other than responses to crashes. These responses were predominantly fuel spill washdowns (1 per 1000 air carrier departures), emergency stand-bys (2 per 1000 air carrier departures), medical responses (10 per 1000 air carrier departures), and other miscellaneous emergencies (2 per 1000 air carrier departures). Based on fees, determined by conferences with local fire prevention and medical authorities, of $277 for a washdown, $651 for a stand-by, $50 for a medical response, and $277 for each miscellaneous response, an average annual benefit of $12.6 million was estimated for non-crash benefits with one exception. That exception is the paramedic function at Atlanta Aiport, which is reported to save 17 heart attack victims each year. Although other cities generally provide such a service by other than airport-based paramedics and cardiac technicians, Atlanta was found to be the only major city that responds with extensively-trained CFR personnel (not just emergency medical technicians) to use defibrillators in the event of a heart attack. This service at Atlanta provides a CFR benefit averaging $7.3 million per year on the basis of a value

of $430,000 for a human life. The total non-crash benefit is, therefore, $19.9 million.

The total estimated benefits of CFR for all classes of aviation are shown in Table ES-5 as a function of airport CFR index. Death/injury benefits and psychological benefits each account for approximately 10% of the total benefit, while aircraft damage and non-crash benefits represent approximately 40% each.

The relationship between the costs and benefits of CFR is shown in Table ES-6. The systemwide ratio of benefits to costs is 0.43 that is, for every $1.00 spent on CFR, there is a benefit of $0.43 The benefit/cost ratio is close to the break-even point of 1.00 only for index D and E airports; for other indexes the benefit/cost ratios are quite low. Looked at in another way, the difference between the annual cost of $115.3 million and the annual benefit of $49.9 million is $65.4 million, which is the portion of the cost for which there is no corresponding benefit. In other words, every time a passenger gets on an air carrier, $0.44 is spent on CFR; an average $0.19 returns as benefit, but $0.25 is not recovered.

It should be emphasized that the benefit/cost ratios in Table ES-6 are upper bounds on the true values. During the course of the study, whenever there was doubt as to what value should be assigned to a benefit, a generous value was assumed in order to insure that benefits were not understated. Thus, if anything, the benefit/cost

Table ES-5: Estimated Annual CFR Benefits, 1966-1978
(Millions of Dollars)

Category	L	A	AA	B	C	D	E	Total
Crash:								
Death/Injury	0.029	0.029	0.065	0.029	0.208	0.029	4.793	5.179
Psychological	0.002	0.032	0.041	0.167	1.111	1.627	2.198	5.179
Aircraft damage	0.157	0.257	0.157	0.157	2.490	4.161	11.590	18.971
Non-Crash:	0.005	0.079	0.099	0.406	2.695	11.257	5.332	19.873
Total	0.193	0.397	0.362	0.759	6.504	17.074	23.913	49.202

Note: Components may not add to totals due to rounding.

Table ES-6: Summary of the Annual Costs and Benefits of CFR

	AIRPORT INDEX								
	NC	L	A	AA	B	C	D	E	Total
Costs (millions of $)	1.393	1.842	7.825	7.058	12.411	42.111	20.313	22.368	115.321
Benefits (millions of $)	0.0	0.193	0.397	0.362	0.759	6.504	17.074	23.913	49.202
Benefit/Cost Ratio	0.0	0.10	0.05	0.05	0.06	0.15	0.84	1.07	0.43

ratios shown are too high.

The conclusion is that, except at index D and E airports, CFR does not pay for itself on a dollars and cents basis. There are two ways to react to this finding. First, one could say that CFR should not be judged solely on a dollars and cents basis; other factors should be taken into account. Second, one could say that CFR should pay for itself on a dollars and cents basis and that the FAA should look for ways of enhancing or retrenching CFR so that the benefit/cost ratios are improved. This report is the first in a series that is designed to identify and evaluate the policy alternatives that are open to the FAA. The ultimate goal is to provide the FAA with the information that is needed to formulate CFR policies that will raise the benefit/cost ratios while maintaining a suitable level of safety.

1.0 INTRODUCTION

1.1 Background

The federal government, the airlines, aircraft manufacturers, and airport operators spend hundreds of millions of dollars every year in order to increase the safety of aviation. This pursuit of safety proceeds along two main avenues. First, actions are taken to decrease the frequency or severity of accidents. For example, high technology navigation aids and landing systems, airport design, airport operating procedures, and many other activities are intended to reduce the number of accidents. Second, given that an accident has occurred, measures are taken to limit the human and property loss that ensues. For example, aircraft design, frequent publicizing of evacuation procedures, and crash/fire/rescue (CFR) programs are intended to limit loss once an accident has occurred. This report deals with the CFR portion of the Federal Aviation Administration's (FAA's) many safety programs.

Since the federal government provides some funding for many of these safety-related programs, the question of allocation of these funds among the programs arises. That is, given a constant level of expenditure, would it be possible for the government to shift dollars from program to program, or within one particular program, so that a higher level of safety could be

attained? This is the general decision-making problem that the government faces. In order to address this problem, it is necessary to have information on the level of safety provided by expenditures on different safety programs. Only when information on the relative merits of the different programs and of the various elements within each program is available can the decision-making problem of allocation of funds be addressed with confidence. This information also can have a bearing on the expenditure of funds on safety by other organizations such as airport authorities.

In 1972, the establishment of Federal Aviation Regulation Part 139, Certification and Operations: Land Airports Serving CAB-Certificated Air Carriers, imposed various requirements on airport operators including the provision of crash/fire/rescue equipment and services in the event of an accident on the airport. Paragraph 139.49, Airport Fire Fighting and Rescue Equipment and Service, specifies increasingly demanding CFR equipment and services as the length of aircraft operating on a regular basis increases at a particular airport. Five major service levels were established by Part 139 and are documented therein. These five major airport "Indexes" and examples of aircraft applicable to each are as follows: Index A (up to 90 feet) - Convair 580, Nord 262, Lockheed Jet Star; Index B (90-126 feet) - BAC 1-11, Boeing 737, DC-9 (except model - 50);

Index C (126-160 feet) - Boeing 707 and 727, DC-8; Index D (160-200 feet) - DC-10, L-1011, DC-8 (stretch); Index E (more than 200 feet) - Boeing 747, Lockheed C-5A, Concorde. These Indexes will be referred to frequently throughout this report.

It is not the objective of this report to evaluate the impact or effectiveness of Part 139 CFR requirements on aviation safety. Rather, the major objective is to provide the basic data relating to the CFR program that will enable the FAA to make future policy decisions regarding CFR. To expand somewhat, one can say that the report has three main purposes.

The first purpose is to locate and to make accessible the raw data on the CFR program. Data pertaining to equipment and manpower costs were obtained from Airport Operations Manuals and Airport Operations Specifications, which are required to be filed with the various regional offices of the FAA by Part 139, and from interviews with airport authorities. Benefit data were determined from aircraft accident records, primarily those of the National Transportation Safety Board (NTSB), and from inspection of airport CFR logs at various locations throughout the country. These data, which were widely scattered and in inconsistent formats, have now been made consistent and are accessible through an automated data base. Much of the data is contained in this report.

The second purpose is to use these data to make an estimate of the costs and benefits of CFR services in general, whether or not required by Part 139. This process entails both defining costs and benefits and carrying out the necessary calculations involving the raw data stated in the previous paragraph.

The third purpose is to take trends into account and to formulate a methodology that will enable the projection of future costs and benefits of CFR. These projections are what would be relevant for future decisions concerning the CFR program. Applications of the projection methodology for various mixes of air traffic and for alternate policy scenarios will enable decisions to be made by the FAA on the basis of all available data.

The compilation and analysis of data were conducted with the support and assistance of a variety of organizations concerned with aviation safety. Besides providing insight into different aspects of CFR and access to many sources of relevant data, representatives of these organizations participated in a review of air carrier accidents to help determine some of the benefits of CFR. The consensus reached by the group with regard to the number of lives saved and aircraft damage reduced by CFR services substantiates the realism of the raw data to be presented later in the report. The entire group, for example, agreed that 98 lives were saved by the prompt, effective action of CFR personnel at Los Angeles International Airport on March 1, 1978,

in response to the aborted take-off of CO603, a DC-10 bound for Hawaii. This ideal example of the potential effectiveness of CFR provides considerable insight into future policy decisions concerning requirements for CFR equipment and services. The support and assistance of the following organizations is much appreciated:

Air Line Pilots Association
Air Transport Association of America
Airport Operators Council International, Inc.
American Association of Airport Executives
Association of Flight Attendants
National Air Transportation Association
National Association of State Aviation Officials
National Business Aircraft Association, Inc.

1.2 Report Organization

The organization of this report is as follows. Chapter 2 describes the way data on CFR cost were gathered, spells out the logic that underlies the calculation of CFR cost, and estimates the 1979 cost for the nation's CFR program. Chapter 3 describes the way the data on CFR benefits were gathered, spells out the logic that underlies the calculation of CFR benefits, and estimates the total CFR benefit for the years 1966-1978. Chapter 4 projects CFR costs over the next fifteen years. Chapter 5 discusses possible methods for projecting CFR benefits and uses one of these methods for projecting benefits over the next

fifteen years. Chapter 6 summarizes CFR costs and benefits.

1.3 A Brief Description of Crash/Fire/Rescue

In order to provide the background needed to understand this report, a brief description of the CFR services provided by airports will be given. As a first approximation, CFR vehicles, firehouses, firefighters, and materials are much like those used in structural firefighting. However, there are a number of differences.

CFR vehicles are typically much bigger and heavier than standard fire trucks. Moreover, these vehicles are equipped to deliver the types of extinguishing agent that are especially effective against aircraft fires. Aqueous film-forming foam (AFFF), for example, is particularly effective in knocking down kerosene fires.

CFR fire stations house the vehicles and, in most cases, the firemen who typically are on duty around the clock at Index C, D, and E airports. FAR Part 139 requires that the first CFR vehicle must be able to reach the midpoint of the farthest air carrier runway within three minutes. This requirement affects how many firehouses there are and where they are placed.

CFR firefighters differ somewhat from conventional firefighters in that aircraft fires differ from structural fires and do

require different firefighting techniques and materials. When fighting an aircraft fire, the firefighters have two main objectives. First, they should determine the avenues of escape open to those inside the aircraft and keep the fire away from those avenues. The CFR firefighter's job is not so much to remove physically the survivors from the burning aircraft; that is the responsibility of the crew. Rather, the CFR firefighter's job is to maintain an environment which will allow the crew to evacuate the aircraft. Second, the CFR firefighters should save as much of the aircraft hull as possible.

In summary, when there is a crash, CFR gets to the scene of the crash and applies techniques appropriate to fighting aircraft fires to save as many people and as much hull as possible. However, since crashes are so rare, CFR is much more frequently called on to provide non-crash services, e.g., washing down fuel spills, putting out grass fires, and responding to medical emergencies.

In order to illustrate what CFR can do, a brief description will be given of the accident that provides the most dramatic example of the benefits that CFR can afford. On March 1, 1978, a Continental Airlines DC10 bound for Hawaii was departing from Los Angeles International Airport with a crew of 14 and 186 passengers, mostly retired vacationers over the age of 60. During take-off several tires blew, causing the pilot to abort the take-off. The aircraft overran the departure end of the runway,

collapsed the thin layer of black top in the overrun area, ruptured a fuel tank in the left wing, and began to burn.

During the take-off roll, one of the tires blew directly in front of one of the fire stations at Los Angeles International Airport. A firefighter who witnessed the incident alerted others within the station, and the first vehicle to respond was under way before the air traffic control tower sounded its alarm. This vehicle arrived at the burning aircraft only seconds after the aircraft had come to rest. Although several of the evacuation slides were melted by the fire, the application of water and foam by CFR personnel protected a sufficient number of exits to allow the crew to evacuate the aircraft with almost complete success. Compared to what would have happened in the absence of CFR, the best estimate is that in this accident CFR saved 98 lives, prevented 19 serious injuries, and saved 30 percent of the aircraft hull from destruction.

1.4 Conventions

Several conventions used in this report will be established here. First, all dollar values appearing are in April 1979 dollars.

Second, costs and benefits are considered for all public use airports under United States jurisdiction with the exception of Alaskan airports and those airports where CFR services are provided by the military. The reason for excluding Alaska is that

the wilderness and severe weather of that region result in many unmanned airports and other unusual operating conditions that are not typical of aviation in the rest of the country. Alaska must be excluded, therefore, since requirements for CFR based on unusual operating conditions should not be allowed to bias the data used for national policy-making. More typical airports in the FAA Pacific and Southern Regions are included, however, including those in American Samoa (Pago Pago), Hawaii, the Marianas Islands, Puerto Rico, and the U.S. Virgin Islands, even though they are outside the Continental United States. Both costs and benefits at airports where CFR service is provided by the military, including Air National Guard service and Air Force bases, are excluded because the service would be provided even in the event of no non-military traffic. Such a condition is not relevant in the context of this study, which con-concerns public aviation.

Finally, complete data on benefits were available for the years 1966 through 1977. However, one accident in 1978 was included—the Continental DC-10 accident at Los Angeles. This was done to avoid biasing CFR benefits downward, which would have resulted from ignoring the most effective application of CFR in aviation history. Thus, the years 1966 through 1978 are covered, but it should be kept in mind that only one accident in 1978 is included.

This report provides much of the information that is needed to make an informed evaluation of the CFR program. The analysis, while not definitive, does provide a much more detailed picture of CFR than previously existed and, therefore, consitutes a significant first step along the road to sound and systematic decision-making.

2.0 CFR COST ANALYSIS

2.1 General Approach

In order to determine the total national cost of CFR equipment and services, four cost categories were established: manpower, vehicles, buildings, and equipment and material. The basis for determining costs in each category was the compilation of information from Aiport Operating Manuals for fully-certificated airports and from Operations Specifications for those airports with limited certificates. These airport documents were examined and the relevant information extracted at each of the FAA's Regional Offices, with the exception of the Alaskan and Pacific Regions. The data extracted in this manner, including vehicle description, manning (professional and auxiliary), manufacturer, year, response time, condition, and extinguishing agent capacities and rates, are contained in Appendix A. Alaskan airports and those with service provided by the military were intentionally excluded from cost calculations for the reasons discussed in Chapter 1. Information on 1 Index E, 1 Index D, 3 Index C, 1 Index B, and 5 Index AA airports in the Pacific Region was estimated by applying averages according to CFR index based on the available data for the rest of the nation.

During the data collection process, interviews with FAA airport inspectors, airport operators, and CFR personnel at a variety of airports throughout the country provided valuable additional

information regarding salaries, overhead expenses, and other cost information not contained in the Operations Manuals. These interviews also provided information on CFR at airports with no certificate—generally busy general aviation airports. Tabulation of these general aviation airports with some CFR capability, including a range from 16 such airports in the Western Region to none in the New England Region, led to a national estimate of 100 non-certificated airports with CFR—an average of 10 airports per region, excluding Alaska. Eight of these airports rank in the top 25 in the country with regard to total aircraft operations—all in excess of 350,000 operations in Fiscal Year 1978 (Ref. 2.1).

All cost calculations were performed as a function of CFR index as well as for the nation as a whole. In general the available airport records were sufficient to provide reliable, consistent data. When the national inventory was analyzed by computer, however, to extract the costs treated in this chapter, only those airports with at least one CFR vehicle located <u>on the airport</u> and not provided by nor manned by the military were considered.

2.2 Manpower

Manpower costs are the greatest element of CFR expense. They were determined by first counting the number of CFR personnel based at every airport in the country and then multiplying the number of personnel by an average salary and benefits figure

estimated from a sample of airports of various Indexes. At airports with a firefighting force large enough to warrant a formal structure with chiefs, captains, lieutenants, engineers (operators), and firefighters, the average salary was weighted according to the distribution of personnel of various ranks. Benefits and overhead expenses, including retirement, health and life insurance, disability, training, and repairs, was included as 30% of the average salary. The total of salaries and benefits used in the computation is as follows:

Index A	$17,022 per annum
Index B	$19,395
Index C	$22,837
Index D	$23,358
Index E	$23,925

Index AA airports, airports with limited certificates, and those without certificates were assigned the Index A salary and benefit figure.

The number of professional personnel only was included in the manpower count as reflected in the Operations Manuals. Auxiliary personnel, who are used most at Index B and smaller airports, are not paid exclusively for the purpose of fighting fires and would continue to be employed in their regular capacities regardless of a requirement for CFR services. The number of professional personnel per shift was multiplied by a "shift factor"

to arrive at a total personnel count. This shift factor was 3 for Index C, D, and E airports, where three shifts are generally employed to staff the fire stations around the clock, 2.5 for Index B airports, 2 for Indexes A and AA and airports with limited certificates, and 1 for airports with no certificates. Firefighting personnel at many of the smaller airports were counted as professionals if they could respond within 3 minutes to an emergency, even though they had other duties, such as maintenance, to perform. The number of personnel at airports without certificates was estimated on the basis of the number of vehicles, 1, at each of the 100 airports and the average number of men per vehicle, 0.6, determined from analysis of the national inventory. Thus, 60 professional firefighters are assumed to be employed throughout the country at airports without FAA certificates. Twenty-one of these are employed at Van Nuys Airport in California, the fourth busiest in the nation in terms of total operations in 1978.

The number of professionals by index and the cost associated with each are presented in Table 2-1. The annual cost of $91.801 million is 80% of the total cost of CFR.

2.3 Vehicles

Cost of airport CFR vehicles was determined by their characteristics as indicated in the Operations Manuals and by an average price obtained from recent manufacturers' quotes and from data

Table 2-1: CFR Manpower by Airport Index

	Number of Professionals	Total Annual Cost ($K)	Number of Airports with Non-Military CFR	Cost per Airport ($K)
Index E	768	18,374 (20.0%)	17	1,081
Index D	699	16,327 (17.8%)	26	628
Index C	1497	34,187 (37.2%)	91	376
Index B	495	9,601 (10.5%)	73	132
Index AA	300	5,107 (5.6%)	83	62
Index A	346	5,890 (6.4%)	152	39
Limited Certificate	76	1,294 (1.4)	36	36
No Certificate	60	1,021 (1.1)	100	10
Total	4,241	91,801	578	

collected from airport personnel. The characteristic used to determine vehicle cost was quantity of extinguishing agent, either water or dry chemical or both. The distribution and estimated cost of the three types of vehicles used in arriving at a total vehicle cost figure are presented in Tables 2-2 through 2-4.

By assuming that the real price of CFR vehicles is constant over time and that the purchase of vehicles is staggered over time from airport to airport, the actual capital expenditure each year is constant. The annual cost of CFR vehicles can be assumed, therefore, to be distributed over the lifetime of the vehicle. Most CFR personnel interviewed agreed on a 15-year vehicle lifetime. Thus, the annual capital costs of vehicles are estimated at 1/15 the current cost of a new vehicle of the capability described in Tables 2-2 through 2-4.

The distribution and annualized cost of vehicles as a function or airport index are presented in Table 2-5. The annual cost of $12.631 million is 11% of the total cost of CFR.

2.4 Buildings

Building costs are also capital costs that are assumed to be spread uniformly over the lifetime of the commodity, but in this case for a period of 25 years. Samples of airport CFR building costs indicate a considerable jump when the building must

Table 2-2: Representative Cost and Distribution of CFR Vehicles with Water/Foam Capability Only

Water Capacity (Gal)	Vehicle Cost ($K)	Number of Vehicles in Service
0-75	10	2
76-160	25	10
161-260	40	8
261-375	75	9
376-675	140	56
676-850	160	19
851-1100	180	71
1101-1750	200	183
1751-2250	220	18
2251-2750	240	23
2751-3500	325	63
3501-4500	435	21
4501-5500	440	11
5501-6500	445	2
6501-9500	450	5

Table 2-3: Representative Cost and Distribution of CFR Vehicles with Dry Chemical Capability Only

Chemical Weight (Lbs)	Vehicle Cost ($K)	Number of Vehicles in Service
0-75	10	21
76-160	20	6
161-260	30	0
261-375	40	25
376-675	50	41
676-850	60	5
851-1100	70	33
1101-1750	80	4
1751-2250	90	1
2251-9500	100	3

Table 2-4: Representative Cost and Distribution of CFR Vehicles with Both Water/Foam and Dry Chemicals

Water Capacity (Gal)	Vehicle Cost ($K)	Number of Vehicles in Service
0-75	20	100 (91 - 50/450)*
76-160	35	113 (95 - 100/450)
161-260	90	52 (39 - 200/1350)
261-375	125	12
376-675	160	133 (61 - 450/450)
676-850	185	17
851-1100	205	43
1101-1750	215	32
1751-2250	225	6
2251-2750	245	9
2751-3500	330	27
3501-4500	440	2
4501-5500	445	1

* This notation means that of the 100 vehicles in this class, 91 had a capacity of 50 gallons of water for foam production and 450 pounds of dry chemical.

Table 2-5: CFR Vehicles by Airport Index

	Number of Vehicles	Total Annual Cost ($K)	Number of Vehicles per Airport	Cost per Airport ($K)
Index E	155	1,905 (15.1%)	9.1	112
Index D	157	2,044 (16.2%)	6.0	79
Index C	355	3,803 (30.1%)	3.9	42
Index B	184	1,701 (13.5%)	2.5	23
Index AA	169	1,418 (11.2%)	2.0	17
Index A	228	1,254 (9.9%)	1.5	8
Limited Certificate	63	373 (3.0%)	1.8	10
No Certificate	100	133 (1.1%)	1.0	1
Total	1,411	12,631		

provide sleeping and living quarters for firefighters as well as a shelter for the CFR vehicles. This jump occurs predominantly between Index B and Index C airports, since the latter almost always are staffed 24 hours per day. There are, of course, exceptions to this tendency, such as Dallas-Fort Worth Regional Airport, where 8-hour shifts are used and no sleeping quarters are provided. (DFW is an Index E airport.) Costs of all buildings are assumed to be proportional to the number of vehicles, and hence firefighters, that they house. A typical three stall fire station with crew quarters costs $600,000 (1979 dollars).

The CFR building expense used to compute annual costs is as follows:

Index A	$50,000/vehicle	($2,000/vehicle/year)
Index B	$100,000/vehicle	($4,000/vehicle/year)
Index C	$200,000/vehicle	($8,000/vehicle/year)
Index D	$200,000/vehicle	($8,000/vehicle/year)
Index E	$200,000/vehicle	($8,000/vehicle/year)

Index AA airports and those with limited or no certificates are treated as Index A airports.

The distribution and annualized total cost of buildings as a function of index are presented in Table 2-6. The annual cost of $7.192 million is approximately 6% of the total cost of CFR.

Table 2-6: CFR Buildings by Airport Index

	Total Annual Cost ($K)	Cost per Airport ($K)
Index E	1,240 (17.2 %)	73
Index D	1,256 (17.5%)	48
Index C	2,840 (39.5 %)	31
Index B	736 (10.2 %)	10
Index AA	338 (4 . 7%)	4
Index A	456 (6 .3 %)	3
Limited Certificate	126 (1.8 %)	4
No Certificate	200 (2.8%)	2
Total	7,192	

2.5 Equipment and Material

One of the major elements of equipment and material for CFR is extinguishing agent, particularly aqueous film-forming foam (AFFF). At approximately $8 per gallon, this substance can cost a great deal of money during an actual emergency or simply for training purposes. Larger airports tend to have more frequent hot drills and more occasions to use AFFF on actual fires, whether aircraft wheel-well fires or structural fires off the airport runways and ramps. San Francisco International Airport, for example, budgets $36,000 per year for extinguishing agent. Even a small Index A airport like Buchanan Field in Concord, California spends approximately $300 for AFFF at each of three hot drills per year.

Expenditures for protective gear (hats, boots, coats, gloves), axes, tools, flashlights, and other items of equipment also occur in proportion to the number of men on a firefighting team and, in general, to airport index as well. Accordingly, the following costs have been estimated for equipment and materials:

	Agent	Gear, tools, and other	Total (per man)
Index A	$450	$200	$650
Index B	503	250	753
Index C	556	300	856
Index D	631	350	981
Index E	706	400	1106

As before, Index AA airports and those with limited or no certificates are treated as Index A airports.

The distribution and total cost of equipment and materials as a function of airport index are presented in Table 2-7. The annual cost of $3.697 million is slightly more than 3% of the total cost of CFR.

2.6 Cost Summary

The total annual cost of CFR equipment and services in the United States is $115.321 million. This cost is broken down by airport index and by expenditure category in Table 2-8. The 43 Index D and Index E airports considered in the calculations account for about 37% of the national cost of CFR. The 134 airports in Indexes C, D, and E—23% of the 578 airports considered—account for 74% of the total national cost.

Table 2-7: CFR Equipment and Material

by Airport Index

	Total Annual Cost ($K)	Cost per Airport ($K)
Index E	849 (23.0%)	50
Index D	686 (18.6%)	26
Index C	1,281 (34.6%)	14
Index B	373 (10.1%)	5
Index AA	195 (5.3%)	2
Index A	225 (6.1%)	1
Limited Certificate	49 (1.3%)	1
No Certificate	39 (1.1%)	0.4
Total	3,697	

Table 2-8: Summary of Annual CFR Costs by Airport Index and Expenditure Category ($K)

	Manpower	Vehicles	Buildings	Equipment	Total by Index
Index E	18,374	1,905	1,240	849	22,368 (19.4%)
Index D	16,327	2,044	1,256	686	20,313 (17.6%)
Index C	34,187	3,803	2,840	1,281	42,111 (36.5%)
Index B	9,601	1,701	736	373	12,411 (10.8%)
Index AA	5,107	1,418	338	195	7,058 (6.1%)
Index A	5,890	1,254	456	225	7,825 (6.8%)
Limited Certificate	1,294	373	126	49	1,842 (1.6%)
No Certificate	1,021	133	200	39	1,393 (1.2%)
Total by Category	91,801 (79.6%)	12,631 (11.0%)	7,192 (6.2%)	3,697 (3.2%)	115,321

References

2.1 FAA Air Traffic Activity, Fiscal Year 1978, Federal Aviation Administration, Office of Management Systems, U.S. Government Printing Office, pp. 49-51.

3.0 CFR BENEFIT ANALYSIS

3.1 General Approach

The purpose of this chapter is to describe and analyze the data that this study has collected on CFR benefits in order to estimate a dollar value for those benefits. The benefits provided by CFR fall into three areas.

1. Preventing property loss. When an aircraft crashes, catches fire, and CFR puts the fire out, this increases the salvage value of the aircraft hull.

2. Preventing human loss. CFR prevents two types of human loss. First, when an aircraft crashes and catches fire, prompt action by CFR can save lives and reduce the number of injuries. Second, insofar as CFR makes flying safer and lowers the level of anxiety and nervousness of passengers, CFR provides a psychological benefit.

3. Non-crash service benefits. CFR can provide benefits if an airport experiences fuel spills, grass fires, structural fires, first aid calls, or similar problems.

The property loss and human loss benefits that CFR provides are examined for air carrier operations in 3.2. Since most CFR benefits result from air carrier operations, this is where the bulk of the effort is concentrated. Brief overviews are given CFR benefits for commuter airlines and air taxi operations in

3.3, and for general aviation in 3.4. Non-crash benefits are discussed in 3.5.

In summary, this chapter estimates the dollar value of the benefits provided by CFR over the period 1966-1978. This gives us an idea of what CFR is capable of doing, and it provides a basis for projecting the benefit that future expenditures on CFR would provide.

3.2 Air Carrier Accidents

3.2.1 The Data

All previous discussions of CFR have been hampered by the fact that there were no good data on the benefits provided by CFR. Various people had anecdotal evidence about what CFR did or did not do in particular cases or at particular airports, but there was no systematic compilation of data that could serve as a foundation for discussion. One of the main purposes of this report is to assemble this data and to make it available to decision-makers and other interested parties.

This section discusses the process by which data on actual, realized CFR benefits were gathered. All U.S. air carrier accidents from 1966 through 1977 were examined. 1966 was chosen as the first year for which to collect data because prior to 1966

piston-driven aircraft, now relatively rare, comprised an important part of the national aircraft fleet. Therefore, data from earlier years would have been of limited relevance to an understanding of the current and future benefits of CFR. 1977 was the last year for which complete accident records were available. However, though records for all 1978 accidents were not available, one accident for which records were available is included in the data. This is the Continental Airlines DC-10 accident that occurred in Los Angeles on March 1, 1978. This accident, in which CFR is estimated to have saved 98 lives and about $10 million worth of hull, is the most dramatic example of an accident in which CFR can provide a sizeable benefit. Thus, the data on benefits cover the years 1966-1978, but it should be kept in mind that only one 1978 accident has been considered in the analysis.

Data on CFR were gathered by taking three passes through the accident records compiled by the National Transportation Safety Board (NTSB). These records included the accident briefs contained in "Annual Review of Aircraft Accident Data - U.S. Air Carrier Operations" for the years 1966-1977, NTSB Aircraft Accident Reports, and the original NTSB accident files.

The various types of accident records contain information of

increasing complexity. The accident briefs used for the initial review, for example, include identifying data for each occurrence, such as date, location, and name of the air carrier involved. There is also a short description of the type of accident, the causal factors, pertinent weather details, and an indication of whether or not fire occurred in the accident.

The complete accident file is usually available in two forms: the published "Blue Book" or NTSB Accident Report, and the actual file, most of which are stored at the Federal Records Center in Suitland, Maryland, although more recent files are held at the NTSB document room at 800 Independence Avenue, SW, Washington, DC. If the blue book was available, it was used to assess CFR benefits. If not, the actual file was used. The more detailed files provide comprehensive discussions of all of the information summarized in the accident briefs as well as other items not covered at all in the briefs. There is a discussion of airport firefighting and rescue facilities and their response to the accident, as well as an account of the survivability of the accident with regard to impact forces and subsequent propagation of fire, if any. Also included is a chronology of the accident, including transcripts of cockpit voice recorders.

The first pass through the records culled out those accidents for which there was definitely no chance of CFR providing any benefit.

These accidents were enroute accidents (such as turbulence accidents, usually involving only one or two moderate injuries), accidents where all occupants were dead on impact, and accidents well away from the immediate vicinity of airports. Of the 628 air carrier accidents from 1966 through 1978 that were reviewed, 406 were determined to have provided no opportunity for a CFR benefit. This left 222 accidents for which CFR possibly provided a benefit.

The second pass through the data examined these 222 accidents in more detail. These 222 accidents are listed in Appendix B. It was determined that 133 of these accidents definitely provided no CFR benefits; these accidents are listed in Appendix C, where the reason why there were no CFR benefits is given. This left 89 accidents for which CFR might have provided benefits.

The third pass through the data studied the remaining 89 accidents in greater detail. For 62 of these accidents, listed in Appendix D and described in Appendix F, the full NTSB records were studied. For the remaining 27 accidents, listed in Appendix E, the full NTBS records were missing; therefore, these accidents were studied by examining the summary NTSB briefs and by making telephone calls. For each accident, estimates were made of the CFR benefits in terms of the number of lives saved, the number of injuries prevented, and the value of the portion of the aircraft hull that was saved by CFR. Most of these accidents were discussed by the working group composed of representatives of the organizations listed

in Chapter 1. The group estimated not only actual CFR benefits but also the benefits that might have resulted from "perfect" CFR with zero response time and from ideal CFR with a three-minute response time. The determination of CFR benefits under the two hypothetical conditions would help to place upper bounds on CFR benefits achievable in the future.

The outcome of the discussions of the working group was agreement on the benefits provided by CFR for each accident. Thus, three numbers have been assigned to each accident:

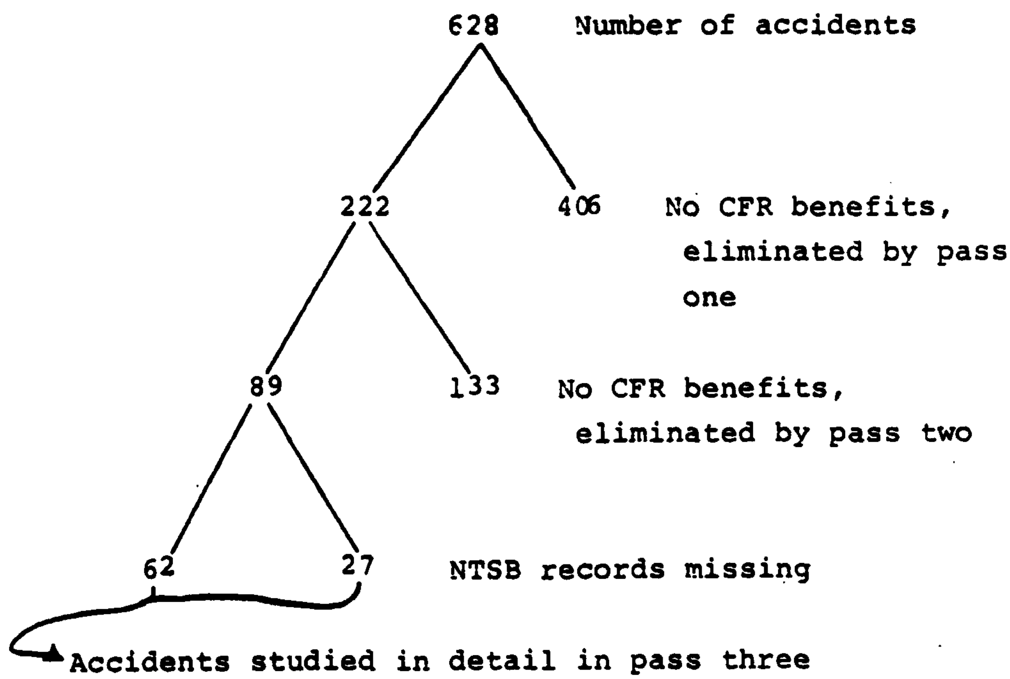
- number of deaths prevented by CFR;
- number of injuries prevented by CFR;
- percentage of the aircraft hull saved by CFR.

This information is given for each accident in Appendix G. For those 42 accidents that actually provided a CFR benefit, this information is given in Table 3-1. Sections 3.2.3 and 3.2.4 are devoted to placing a dollar value on these benefits. (The numbers in parentheses in Table 3-1 show lives lost due to fire and, hence, lives that could have been saved by perfect CFR. For more details, see Appendix G.) Figure 3-1 summarizes the way that the 628 air carrier accidents were treated in the three passes. It is not likely that additional information regarding those accident for which the detailed National Transportation Safety Board records were not available would change the benefit analysis significantly.

Table 3-1: Air Carrier Accidents that Provided an Actual CFR Benefit, 1966-1978

Date	CFR Index	Location	Aircraft	Percent of Hull Saved	Lives Saved	Injuries Prevented
6-17-66	C	Chicago/Midway	CV440	80	0	0
10-18-66	E	Los Angeles	B707	20	0	0
11-26-66	C	Oakland	B707	10	0	0
1-23-67	E	San Juan	CV640	50	0	0
2-17-67	D	Atlanta	M404	10	0	0
4- 8-67	E	Chicago/O'Hare	Nord 262	70	0	0
4-25-67	E	San Juan	CV640	60	0	0
7-23-67	C	Des Moines	CV340	60	0	0
11- 6-67	D	Erlanger	B707	25	0	0
7- 2-68	D	Philadelphia	DC7	50	0	0
12-27-68	E	Chicago/O'Hare	CV580	20	0	0
6-24-69	A	Moses Lake	CV880	10	0 (2)	0
10-16-69	C	Stockton	DC8	10	0	0
3- 4-70	D	New York/LGA	S61L	100	0	0
5-18-70	E	San Francisco	L382	80	0	0
6- 9-70	C	Bangor	DC8	20	0	0
9- 3-70	E	New York/JFK	DC8	5	0	0
12-28-70	C	St. Thomas	B727	20	0	0
6- 7-71	AA	New Haven	CV580	0	1	0
8- 8-71	E	Honolulu	Viscount	85	0	0
12-17-71	E	Houston	BE99	10	0	0
5-10-72	D	Atlanta	DC9	85	0	0
5-18-72	D	Ft. Lauderdale	DC9	20	0	0
5-30-72	E	Ft. Worth/GSW	DC9	10	0 (1)	0
8-13-72	E	New York/JFK	B707	85	0	0
9- 1-72	E	New York/JFK	B747	95	0	4
11- 1-72	D	St. Louis	B707	95	0	0
3- 5-73	D	Denver	B707	75	0	0
6-20-73	C	Bangor	DC8	70	0	0
6-23-73	E	New York/JFK	DC8	90	0	0
8- 8-73	E	Washington/IAD	B727	10	0	0
11- 3-73	E	Boston	B707	25	0	0
12-17-73	E	Boston	DC10	75	0	0
12-17-73	C	Greensboro	DC9	75	5	0
1- 4-74	D	Tampa	B727	95	0	0
6-24-75	E	New York/JFK	B727	0	9	0
8-16-75	C	Portland	B727	95	0	0
8-25-75	E	New York/JFK	DC10	80	20	17
2-16-76	D	Denver	B727	90	0	0
4-27-76	C	St. Thomas	B727	5	0 (17)	0
11-16-76	D	Denver	DC9	25	0	0
3- 1-78	E	Los Angeles	DC10	30	98 (2)	19

Figure 3-1: Disposition of the 628 Air Carrier Accidents, 1966-1978



The accidents of foreign air carriers in the United States are included in the data base. Accidents that occurred in Alaska were excluded for the reasons discussed in Chapter 1, as were accidents involving amphibious aircraft or seaplanes landing in the water and all accidents in Vietnam and other areas of Southeast Asia during the late 1960's.

3.2.2 Descriptive Statistics Relevant to CFR

Some of the data on CFR accidents that were gathered in the course of preparing this report will now be displayed in figures and tables to give the reader a feel for the number of accidents, the number of people involved, the value of aircraft hulls involved, and how these have varied over time. These statistics are now available for the first time.

Figure 3-2 shows the number of air carrier accidents from 1966 to 1977 for which CFR might have provided a benefit; these are the 222 accidents referred to in 3.2.1. It is true that CFR did not provide a benefit in all these accidents, but these are chosen as the "CFR-relevant" accidents which might well have provided a CFR benefit if conditions had been a little different. (The graph for accidents in which CFR provided an actual benefit is not shown; the small sample makes such a graph difficult to interpret.) It is seen that the number of accidents goes down fairly steadily over time. Possible explanations for this are

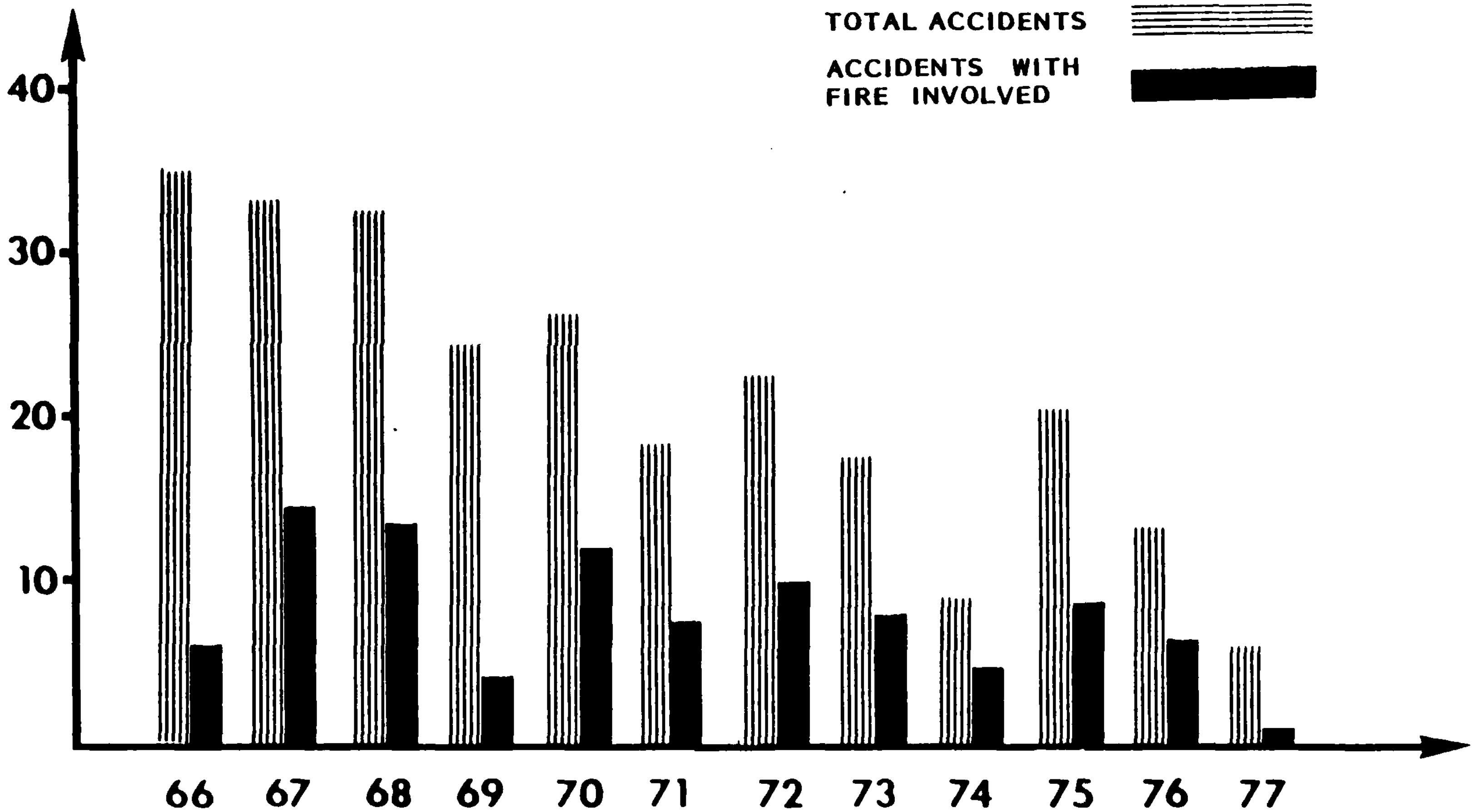


FIG. 3 - 2

NUMBER OF CFR RELEVANT ACCIDENTS
1966 - 1977

the declining number of operations over the last five years, safer technology, and greater pilot familiarity with jet aircraft, which were mainly introduced into the fleet in the 1960's.

Figure 3-3 shows the average number of occupants for CFR-relevant accidents. It is seen that this curve has an upward trend, with the last two years probably representing a statistical artifact. The explanation for this trend is simply that as bigger aircraft are used, the number of occupants in crashes goes up accordingly.

The last two figures showed that the number of CFR-relevant accidents has been going down while the average number of occupants per plane has been going up. Figure 3-4 shows that these two forces have roughly canceled each other out, and the number of occupants exposed to CFR-relevant accidents has stayed fairly constant over the years, though with significant year-to-year variations. The conclusion is that despite the decreasing number of CFR-relevant accidents, the importance of CFR in terms of the number of people involved in those accidents has remained about the same.

Figure 3-5 shows the annual values of the aircraft hulls involved in CFR-relevant accidents. (The procedure for valuing hulls is described in 3.2.3). It is again seen that despite the decreasing number of accidents, the value of hulls involved has remained fairly constant over the years; again, there is significant year-

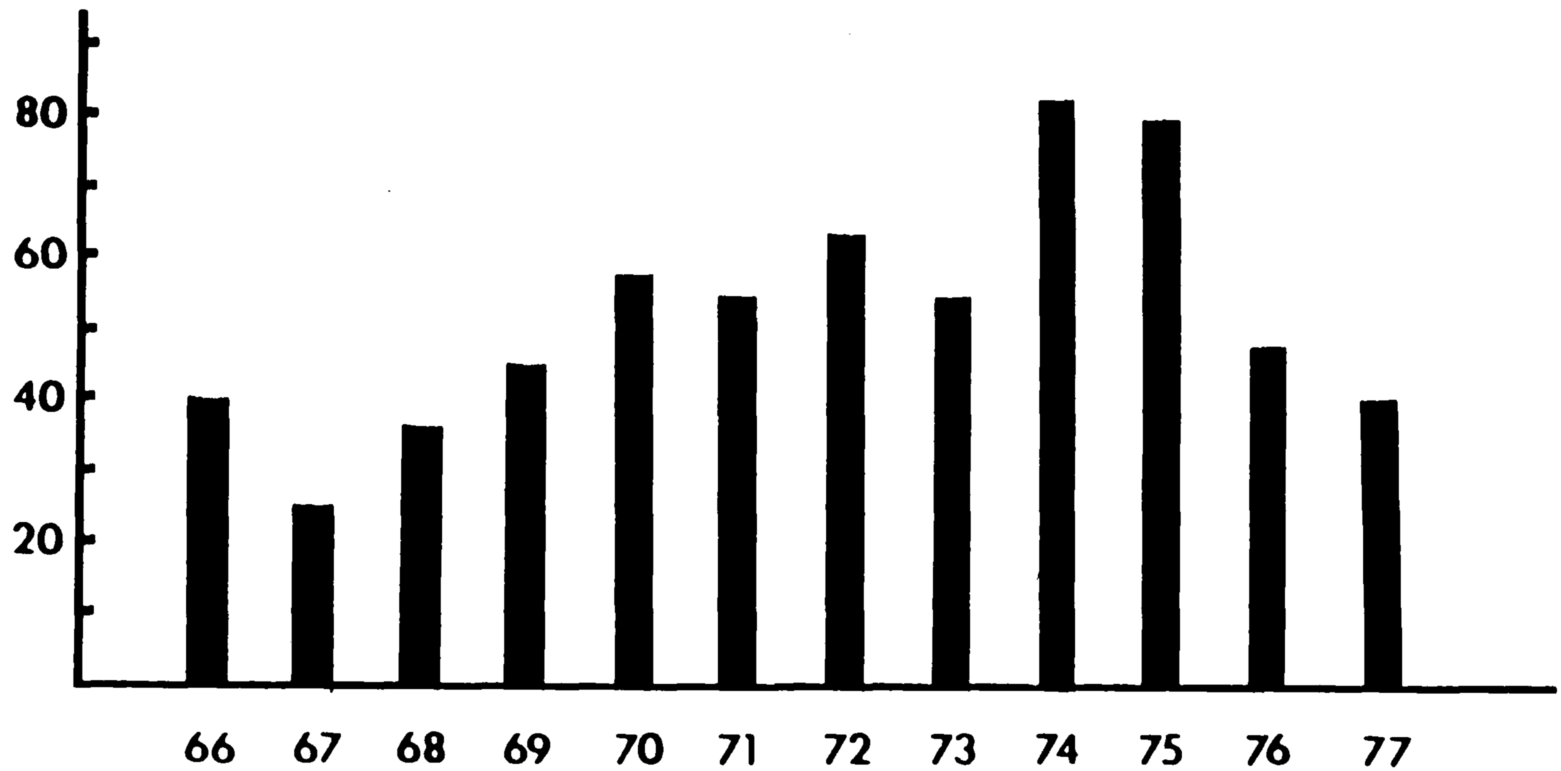


FIG. 3 - 3

AVERAGE NUMBER OF OCCUPANTS
PER CFR RELEVANT AIR CARRIER ACCIDENT
1966 - 1977

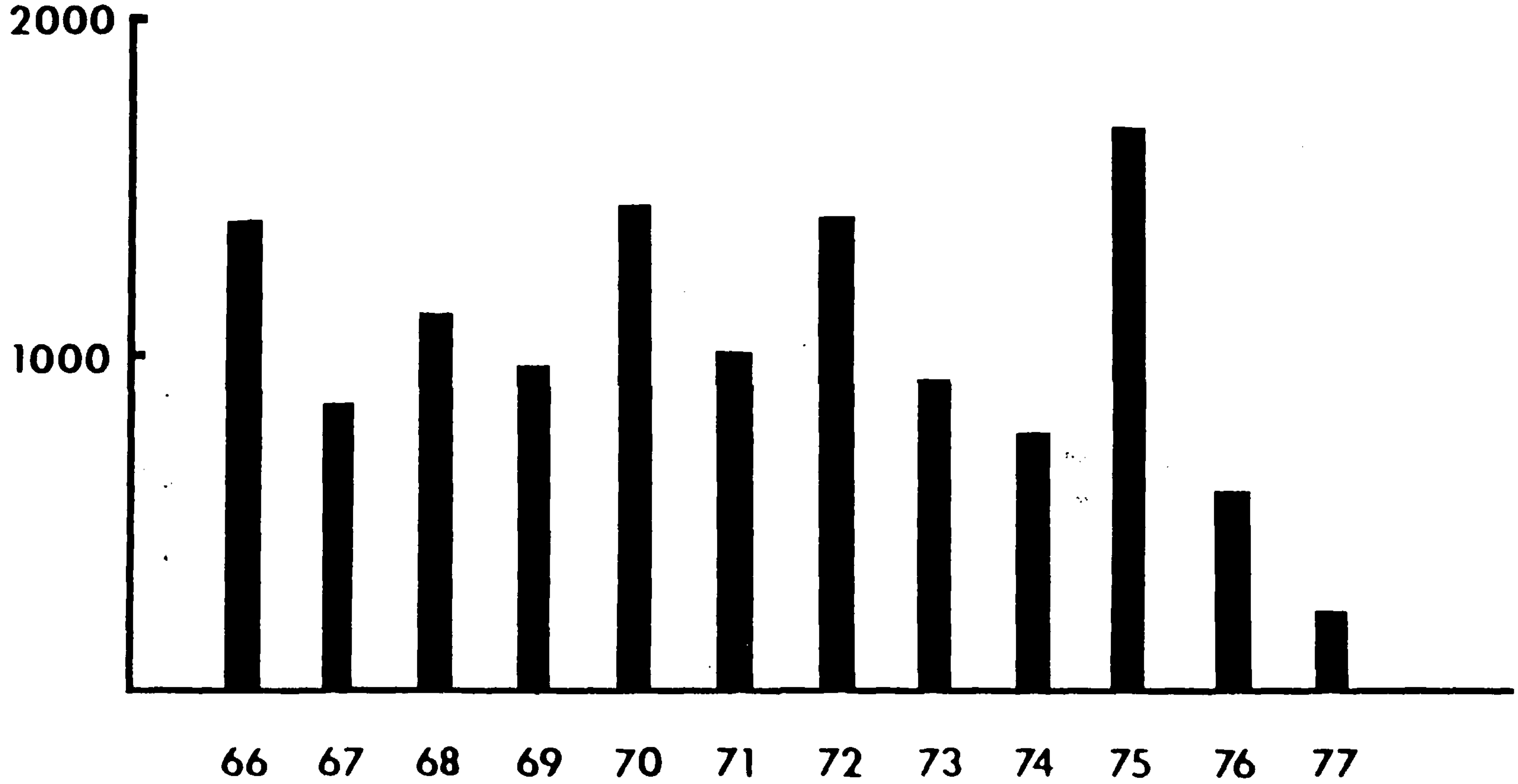


FIG. 3 - 4

NUMBER OF OCCUPANTS EXPOSED ANNUALLY
TO CFR RELEVANT AIR CARRIER ACCIDENTS
1966 - 1977

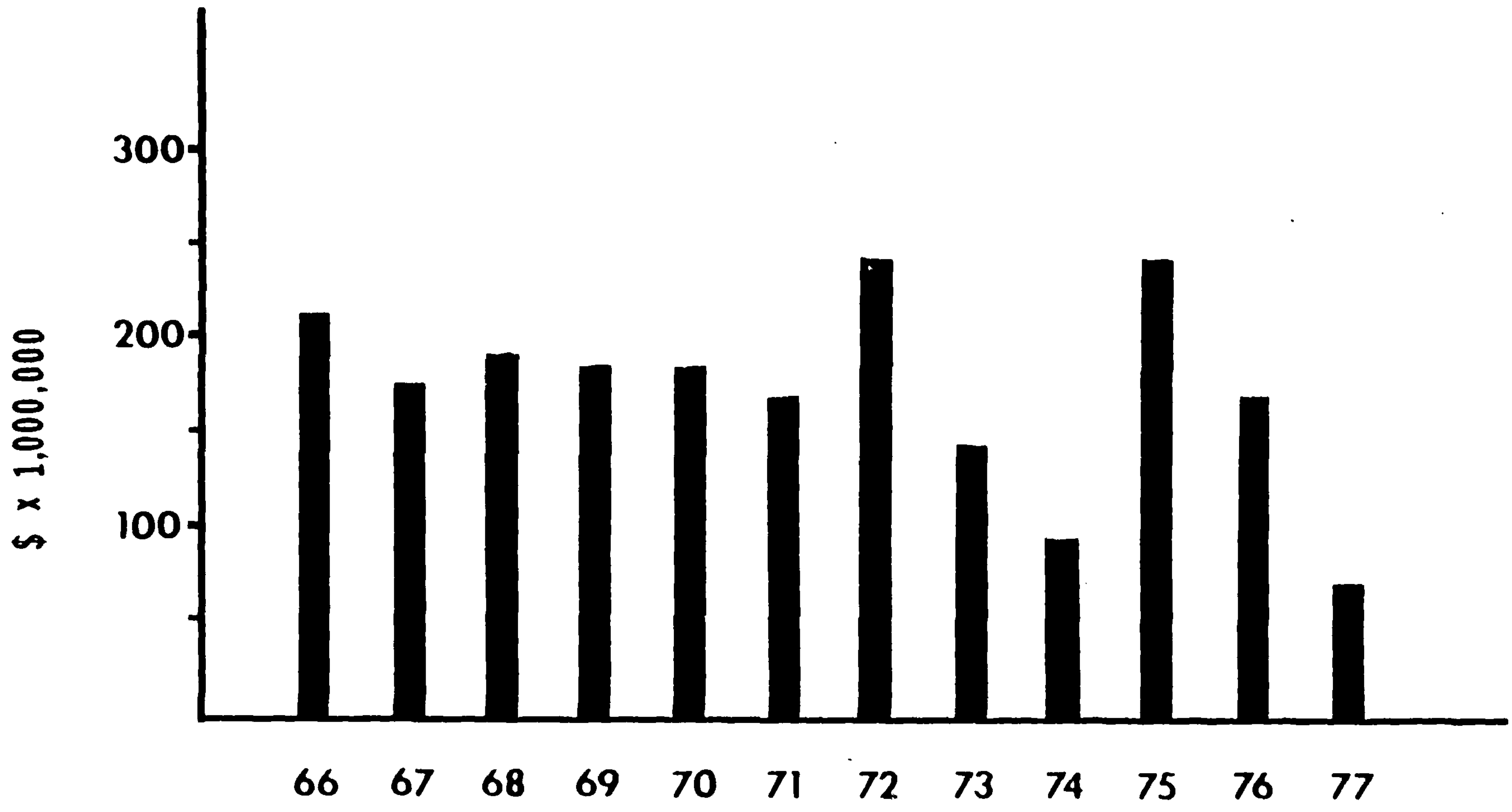


FIG. 3 - 5

VALUE OF HULLS EXPOSED ANNUALLY
IN CFR RELEVANT AIR CARRIER ACCIDENTS
1966 - 1977

to-year variation.

Turn now from the potential CFR benefits to the actual, realized benefits that were turned up in the search of the NTSB records. Table 3-2 shows the number of lives saved by CFR *each year;* for purposes of comparison, the total number of air carrier fatalities is shown. The last column shows the percentage of potential fatalities that were saved by CFR. "Potential fatalities" is defined to be the sum of actual fatalities and the number of lives saved by CFR. It is seen that over 1966-1978, of the potential fatalities in air carrier accidents, CFR managed to save 4.06 percent of them. Moreover, 74 percent of the lives saved by CFR over this thirteen-year period were in the one accident in 1978. In most years, CFR saved no lives.

3.2.3 Placing a Dollar Value on the Property Loss Prevented by CFR

Table 3-1 shows how much of the aircraft hull CFR was able to save in each of the accidents where CFR provided an actual benefit. The task now is to determine for each year and each airport index the value of aircraft hulls that were saved by CFR. The method used is to determine first a value for the hull and then to multiply this value by the percentage of the hull that was saved.

Table 3-2: Number of Lives Saved by CFR, Number of Air Carrier Fatalities, and Percentage of Potential Fatalities Saved by CFR, 1966-1978

Year	Lives Saved by CFR	Total Air Carrier Fatalities	Percent of Potential Fatalities Saved by CFR
1966	0	272	0.00
1967	0	236	0.00
1968	0	349	0.00
1969	0	158	0.00
1970	0	146	0.00
1971	1	203	0.05
1972	0	190	0.00
1973	5	227	2.20
1974	0	467	0.00
1975	29	124	23.39
1976	0	45	0.00
1977	0	656	0.00
1978	98	154	63.64
Total	133	3277	4.06

The assumed value of the hull for each relevant type of aircraft is given in Table 3-3. These values are based on those derived in previous FAA studies of accident cost performed within the Office of Aviation System Plans. They are replacement costs based on reasonable market values at the time of the occurrence averaged over the period of the review (1966-1977). The values are expressed in 1979 dollars.

Where a benefit is assumed to have occurred in an aircraft accident, the portion of the hull saved was estimated. Multiplying the relevant hull value by the percentage of the hull saved gives the value of the aircraft hulls saved by CFR. These values are given for each year and for each airport index in Table 3-4. It is seen that the total value of the property saved by CFR is $214.45 million over this time period. It is also seen that the bulk of the benefits accrues at the larger airports; the Index A, AA, and B airports and those with limited certificates account for only $1.2 million, which is 0.56 percent of the total benefit.

Table 3-3: Value of the Hull of Each Type of Aircraft

Type of Aircraft	Value of the Hull ($ million)
Wide-body Jet (e.g. B747, DC10)	35.0
Four-engine Jet (e.g. B707, CV880, DC8)	12.0
Three-engine Jet (e.g. B727)	8.0
Two-engine Jet (e.g. B737, DC9)	6.0
Four-engine Turboprop (e.g. CL44, L382, Viscount)	4.0
Two-engine Turboprop (BE99, CV580, CV640, N262)	2.0
Four-engine Piston (DC4, DC7)	1.0
Two-engine Piston (CV340, CV440, M404)	0.5
Helicopter (e.g. S61L)	1.5
Light Aircraft	1.0

Source: Reference 3.13.

Table 3-4: Value of Aircraft Hulls Saved in Air Carrier Accidents by CFR, 1966-1978 (Millions of Dollars)

	Airport Index							
Year	L	A	AA	B	C	D	E	Total
1966					1.60		2.40	4.00
1967					0.30	3.05	3.60	6.95
1968						0.50	0.40	0.90
1969		1.20			1.20			2.40
1970					4.00	1.50	3.80	9.30
1971							3.60	3.60
1972						17.70	44.05	61.75
1973					12.90	9.00	40.85	62.75
1974						7.60		7.60
1975					7.60		28.00	35.60
1976					0.40	8.70		9.10
1977								0.00
1978							10.50	10.50
Total	0.00	1.20	0.00	0.00	28.00	48.05	137.20	214.45

3.2.4 Placing a Dollar Value on the Human Loss Prevented by CFR

The benefits provided by CFR in preventing human loss fall into two areas. First, CFR provides the benefit of reducing the number of deaths and injuries resulting from accidents. The number of deaths and injuries prevented by CFR in air carrier accidents from 1966 to 1978 has been estimated by going through the NTSB records, as explained in 3.2.1. The figures for the number of deaths and injuries prevented by year and airport index, drawn from Appendix G, are shown in Tables 3-5 and 3-6, respectively. The question of how to value these deaths and injuries in terms of dollars is postponed for a few paragraphs.

However, at this stage it should be remarked that there is no necessary reason why these lives and injuries must be expressed as dollar values. Instead of representing benefits as a single dollar value, benefits could be expressed as three values—dollars, lives, and injuries, where the saved hulls and the non-crash benefits are expressed as dollars, but lives and injuries are not. This approach has the advantage of avoiding the delicate question of how to turn lives into dollars; the disadvantage is that it is easier to base decision-making on one value rather than three. For a discussion of both the theoretical and practical aspects of decision-making based on more than one attribute, consult Ref. 3.7.

Table 3-5: Number of Lives Saved by CFR in Air Carrier Accidents, 1966-1978

	Airport Index							
Year	L	A	AA	B	C	D	E	Total
1966								0
1967								0
1968								0
1969								0
1970								0
1971			1					1
1972								0
1973					5			5
1974								0
1975							29	29
1976								0
1977								0
1978							98	98
Total	0	0	1	0	5	0	127	133

Table 3-6: Number of Injuries Prevented by CFR in Air Carrier Accidents, 1966-1978

Year	L	A	AA	B	C	D	E	Total
	Airport Index							
1966								0
1967								0
1968								0
1969								0
1970								0
1971								0
1972							4	4
1973								0
1974								0
1975							17	17
1976								0
1977								0
1978							19	19
Total	0	0	0	0	0	0	40	40

The second type of benefit that CFR provides, at least potentially, is the psychological benefit of reducing the level of anxiety among passengers. That is, it is well-known that some people become nervous and upset when flying. If flying could somehow become perfectly safe, then presumably these people would no longer be nervous and upset; this is something that these people would pay some amount of money to achieve, and this is a benefit. Therefore, insofar as flying is made safer, though not perfectly safe, it seems likely that at least some passengers will be less anxious and more serene. This is termed the psychological benefit of CFR. That is, not only does CFR prevent deaths and injuries, but it also arguably provides psychological benefits by making nervous passengers a little less anxious and a little more serene. Two questions arise concerning these psychological benefits of CFR: How important are these benefits? How are they measured?

The importance of the psychological benefits of CFR cannot be definitively determined at this time, but some remarks can be made. While it is undeniably true that some people become very nervous while flying, casual observation indicates that this trait is disappearing as modern man becomes used to air travel and to its low accident rates. Moreover, even insofar as there is nervousness, CFR only abates it somewhat. For example, as Table 3-2 shows, of the potential air carrier fatalities from 1966 to 1978, CFR only prevented roughly 4 percent

of these potential deaths. This suggests that psychological benefits, while of some importance, do not bulk large in the benefits provided by CFR.

But, how in principle, would one go about measuring these psychological benefits? Careful study of this question leads to the conclusion that there is no way to measure the pure psychological benefit standing alone; but it is possible to measure the total human benefit of CFR, including the benefit of saving lives, the benefit of preventing injuries, and the psychological benefit. That is, using the currently accepted method of valuing improved safety, the human benefit as a whole can be measured even though its components cannot. This method, called the willingness-to-pay approach, has been developed by economists over the last 10 years; the basic publications are Refs. 3.1 through 3.11 (excluding Ref. 3.7). This modern approach will now be explained.

Suppose that the decision of whether to have CFR at a particular airport is being considered. A particular person who uses that airport is then made aware of what CFR does and what the consequences of having the CFR at that airport are likely to be. It is then determined in some way, perhaps by asking this person, what the maximum amount is that this person would pay in order to have CFR at this airport. Let the maximum amount that this person would be willing to pay personally in order to have CFR be symbolized by M. M is then interpreted as the dollar value of CFR to this person; M is how much this person is willing to pay

for the services that CFR provides. Therefore, M includes the value of the possibility that CFR will save the life of this person or others, the possibility that CFR will prevent injuries, <u>and</u> the psychological benefits provided by CFR. M is the sought-after dollar measure of the human benefit of CFR for this person. For purposes of cost-benefit analysis, the M's of all individuals are added together, and this is the total dollar benefit of CFR. This is the number that is compared to cost.

It should be pointed out that this willingness-to-pay approach is based on an ex ante evaluation of CFR. That is, the person is asked to place a value on CFR for a given time period, and he does this <u>before</u> the time period begins. This is to be contrasted with an ex post approach in which the value of CFR for a given time period is estimated <u>after</u> that time period is over. It should be emphasized that the ex ante approach is unquestionably the proper approach to use for purposes of decision-making. The only way to make a decision is to base it on the prospective benefits in a coming period. The ex post approach cannot be used for decision-making, since by the time a period is over and an ex post evaluation of benefits can be carried out, it is obviously too late to use that evaluation to decide what decision should be made for that time period. It is true, nevertheless, that the ex ante evaluation of a future time period is often based on an ex post evaluation of a past time period, since the past is one of the main guides to the future.

Another advantage of the ex ante approach is that it allows the psychological benefits to be measured, as explained above. In contrast, the ex post approach, while it can count deaths and injuries prevented, has no way of measuring and valuing the anxiety prevented. Therefore, the ex ante, willingness-to-pay approach has the double advantage of being the only approach that is appropriate for decision-making and that can measure psychological benefits.

The value of a life can be derived in the willingness-to-pay approach in the following way. Suppose that a person is willing to pay $0.30 to reduce his probability of death by one in a million. Now suppose there are one million people each of whom is willing to pay $0.30 for a reduction in probability of death of one in a million. Thus, with a million people each receiving a reduction of one in a million in the probability of death, it is expected that one death will be prevented. With one million people paying $0.30 each for this reduction in the probability of death, as a whole they pay $300,000. That is, $300,000 is paid to prevent one expected death, and this is defined to be the value of a life. Similarly, the value of an injury can be defined.

In summary, the willingness-to-pay method is the theoretically appropriate way to value the human benefits provided by CFR. However, no willingness-to-pay study of CFR has been carried out;

and indeed, it is not clear that such a study would be feasible. Therefore, the value of human benefits is approximated by the equation

$$HB = L\,V_L + I\,V_I + V_P$$

where the symbols have the following definitions:

- HB: value of the human benefits provided by CFR
- L: number of lives saved by CFR
- V_L: value of a single life
- I: number of injuries prevented by CFR
- V_I: value of a single injury
- V_P: total value of the psychological benefits provided by CFR.

Over the period 1966-1978, the number of deaths and injuries prevented by CFR has been determined and is shown in Tables 3-5 and 3-6. The values provided by the FAA for the value of a life and of a serious injury are \$300,000 and \$45,000, respectively, in 1974 dollars. Therefore, in April 1979 dollars we have V_L = \$430,000 and V_I = \$64,000.

Thus, the only term in the equation for HB that has not yet been given a value is V_P, the value of psychological benefits. Unfortunately, a major study would have to be carried out to measure V_P, and this study has not been done. Therefore, all that can be done is to estimate the value of V_P. One suspects that the more deaths and injuries that are prevented by CFR, the more CFR would

allay nervousness and the higher V_P would be. To capture this fact, V_P is tentatively assumed to be given by

$$V_P = \alpha (L\ V_L + I\ V_I),$$

where α is an unknown. For purposes of calculation, we assume that α=1.0. That is, it is assumed that the psychological benefits are equal to the dollar benefits of preventing deaths and injuries. This assumption, which, if anything, seems to overstate the psychological benefits, is made to ensure that benefits are not understated. It must be admitted that this method of placing a value on the psychological benefits of CFR contains considerable uncertainty, but there is no alternative, since no detailed study of these psychological benefits has been carried out. Nevertheless, this ambiguity over the psychological benefits in no way cripples this study, since, as will be seen, the conclusions are not sensitive to even large changes in the psychological benefits.

We can now write the dollar value of the human benefit of CFR as

$$HB = 430{,}000\,L + 64{,}000\,I + 1.0\,(430{,}000\,L + 64{,}000\,I) \quad (3.1)$$

To calculate the human benefits for 1966-1978, substitute into equation (3.1) the values of 133 and 40 for L and I, respectively, and find that

$$HB = \$119{,}500{,}000$$

The conclusion, therefore, is that over the period 1966-1978 CFR provided $119,500,000 in benefits in terms of lives saved, injuries prevented, and psychological benefits.

This aggregate figure will now be broken down by year and airport index. Table 3-7 shows the benefits for each year. The yearly benefits for saving lives and preventing injuries are obtained by multiplying the figures in Tables 3-5 and 3-6 by $430,000 and $64,000, respectively. The total benefit for saving lives and preventing injuries is seen to be $59,750,000; therefore, by assumption, the total psychological benefit is also $59,750,000. The following approach is used to allocate this total psychological benefit among the individual years.

Table 3-8 shows the number of revenue passenger enplanements for 1966-1978 and each year's percentage of the total enplanements for these years. Each year's psychological benefit is obtained by multiplying that year's percentage of enplanements by the psychological benefit for the entire period. For example, for 1966, the psychological benefit is $2,706,675=$59,750,000 x 0.0453. The rationale for this approach is that the psychological benefits are closely related to the amount of passenger activity. An alternative approach would be to assume that the psychological benefit in each year is proportional to the value of lives saved and injuries prevented in that year. This approach is not used, however, since it suffers from the flaw of assigning zero

Table 3-7: Benefits Provided by CFR in Air Carrier Accidents, 1966-1978 (Millions of Dollars)

Year	Lives	Injuries	Psychological	Total
1966	0	0	2.707	2.707
1967	0	0	3.274	3.274
1968	0	0	3.722	3.722
1969	0	0	3.967	3.967
1970	0	0	4.254	4.254
1971	0.43	0	4.314	4.744
1972	0	0.256	4.684	4.940
1973	2.15	0	5.013	7.163
1974	0.00	0	5.133	5.133
1975	12.47	1.088	5.055	18.613
1976	0	0	5.491	5.491
1977	0	0	5.921	5.921
1978	42.14	1.216	6.214	49.570
Total	57.19	2.560	59.750	119.500

Note: Components may not add to totals due to rounding.

Table 3-8: Revenue Passenger Enplanements for U.S. Air Carriers, 1966-1978 (Millions)

Year	Revenue Passenger Enplanements	Percentage of Total
1966	111.0	4.53
1967	134.4	5.48
1968	152.9	6.23
1969	162.9	6.64
1970	174.7	7.12
1971	177.0	7.22
1972	192.4	7.84
1973	205.8	8.39
1974	210.6	8.59
1975	207.5	8.46
1976	225.5	9.19
1977	243.1	9.91
1978	255.0	10.40
	2,452.8	

Notes: (a) Prior to 1970, carriers reported revenue passenger originations, not revenue passenger enplanements.

(b) The figure for 1978 is estimated.

psychological benefits to years such as 1977 in which no lives were saved or injuries prevented; this is an intuitively unacceptable result, since one expects psychological benefits to accrue continuously with airport activity.

It now remains to break each year's benefit down by airport index. The value of lives saved and injuries prevented is easily broken down using the figures in Tables 3-5 and 3-6; the sum of the value of lives saved and the value of injuries prevented is shown in Table 3-9, broken down by year and airport index. Each year's psychological benefit is broken down by airport index by assuming that the percentage of the year's psychological benefit assigned to an index equals the percentage of the year's revenue passenger enplanements that occur at that index.

Table 3-10 shows the percentage of the year's revenue passengers for each index for 1978, which is assumed to be a representative year. Thus, for example, 42.44 percent of each year's psychological benefits are assigned to Index E airports. Each year's psychological benefits can now be broken down by index, and the results are shown in Table 3-11. Adding Tables 3-9 and 3-11 yields Table 3-12, which is the dollar value of the human benefit provided by CFR, broken down by year and airport index.

Table 3-9: Benefits Provided by CFR in Preventing
Air Carrier Deaths and Injuries
Broken Down by Year and Airport Index
(Millions of Dollars)

	Airport Index							
Year	L	A	AA	B	C	D	E	Total
1966	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0
1971	0	0	0.430	0	0	0	0	0.430
1972	0	0	0	0	0	0	0.256	0.256
1973	0	0	0	0	2.150	0	0	2.150
1974	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	13.558	13.558
1976	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	43.356	43.356
Total	0	0	0.430	0	2.150	0	57.170	59.750

Table 3-10: Number of Enplaned Revenue Passengers by Airport Index, 1978

Index	Number of Enplaned Revenue Passengers	Percentage of Total
E	111,323,447	42.44
D	82,423,808	31.42
C	56,271,846	21.45
B	8,480,008	3.23
AA	2,078,976	0.79
A	1,656,755	0.63
Limited	100,000	0.04
	262,334,840	100.00

Notes: (a) Enplanements obtained from Airport Activity Statistics of Certificated Route Air Carriers, 12 Months Ended December 31, 1978, Civil Aeronautics Board, Federal Aviation Administration; airport indexes obtained from FAA airport certification list, January 1979.

(b) Limited certificate category estimated on the basis of 50 airports at 2,000 enplaned passengers each.

Table 3-11: Psychological Benefits Provided by CFR for Air Carriers Broken Down by Year and Airport Index (Millions of Dollars)

	Airport Index							
Year	L	A	AA	B	C	D	E	Total
1966	0.001	0.017	0.021	0.087	0.581	0.851	1.149	2.707
1967	0.001	0.021	0.026	0.106	0.702	1.029	1.389	3.274
1968	0.001	0.023	0.029	0.120	0.798	1.169	1.580	3.722
1969	0.002	0.025	0.031	0.128	0.851	1.246	1.684	3.967
1970	0.002	0.027	0.034	0.137	0.912	1.337	1.805	4.254
1971	0.002	0.027	0.034	0.139	0.925	1.355	1.831	4.314
1972	0.002	0.030	0.037	0.151	1.005	1.472	1.988	4.684
1973	0.002	0.032	0.040	0.162	1.075	1.575	2.128	5.013
1974	0.002	0.032	0.041	0.166	1.101	1.613	2.178	5.133
1975	0.002	0.032	0.040	0.163	1.084	1.588	2.145	5.055
1976	0.002	0.035	0.043	0.177	1.178	1.725	2.330	5.491
1977	0.002	0.037	0.047	0.191	1.270	1.860	2.513	5.921
1978	0.002	0.039	0.049	0.201	1.333	1.952	2.637	6.214
Total								59.750

Note: Components may not add to totals due to rounding.

Table 3-12: Human Benefits Provided by CFR for Air Carriers Broken Down by Year and Airport Index (Millions of Dollars)

	Airport Index							
Year	L	A	AA	B	C	D	E	Total
1966	0.001	0.017	0.021	0.087	0.581	0.851	1.149	2.707
1967	0.001	0.021	0.026	0.106	0.702	1.029	1.389	3.274
1968	0.001	0.023	0.029	0.120	0.798	1.169	1.580	3.722
1969	0.002	0.025	0.031	0.128	0.851	1.246	1.684	3.967
1970	0.002	0.027	0.034	0.137	0.912	1.337	1.805	4.254
1971	0.002	0.027	0.464	0.139	0.925	1.355	1.831	4.744
1972	0.002	0.030	0.037	0.151	1.005	1.472	2.244	4.940
1973	0.002	0.032	0.040	0.162	3.225	1.575	2.128	7.163
1974	0.002	0.032	0.041	0.166	1.101	1.613	2.178	5.133
1975	0.002	0.032	0.040	0.163	1.084	1.588	15.703	18.613
1976	0.002	0.035	0.043	0.177	1.178	1.725	2.330	5.491
1977	0.002	0.037	0.047	0.191	1.270	1.860	2.513	5.921
1978	0.002	0.039	0.049	0.201	1.333	1.952	45.993	49.570
Total	0.023	0.377	0.902	1.928	14.965	18.772	82.527	119.500

Note: Components may not add to totals due to rounding.

A word should be said about the accuracy of the figure used here for the value of life. There are two different ways to apply the willingness-to-pay approach in order to obtain a value of life. The first method is to infer the value of life from observed behavior. For example, Thaler and Rosen (Ref. 3.10) infer from wage differentials among risky jobs that the value of life to an individual is $422,000. Blomquist (Ref. 3.3) infers from seat-belt usage that the value of life to an individual is $400,000. The second method of arriving at the value of life is to ask a person directly how much he would pay to decrease his probability of death by a given amount. Acton (Ref. 3.1, Ch. VI) uses a questionnaire about heart attacks to infer a value of life of $47,000. Jones-Lee (Ref. 3.6, Ch. 6) uses a questionnaire to derive a value of life of something over a million dollars. (All figures in this paragraph are in April 1979 dollars.)

It is seen that the value of life figure provided by the FAA, while not derived by an ex ante, willingness-to-pay approach, is fairly close to typical values that some studies using this approach have found. Nevertheless, no consensus on the value of life has yet emerged from the literature. Future work could carry out a willingness-to-pay approach that dealt with the specific features of CFR; this would both provide a figure for the value of life and also provide a measurement of the psychological benefits of CFR.

3.3 Commuter Airline and Air Taxi Accidents

All accident briefs for commuter and air taxi accidents from 1973 through 1978 were examined, and it was found that there were 246 which involved fire and which were fairly close to an airport. There were 58 fatalities in these accidents. It is estimated that CFR saves 0.5 lives per year in these accidents. This figure, which is probably an overstatement of CFR benefits, is based on general considerations rather than on a reading of detailed accident reports, which often do not exist. These general considerations include the ease of self-evacuation in the small aircraft typically used by commuter airlines and air taxis and the lack of CFR at many of the airports where commuters and air taxis operate.

Of the 246 accidents examined, only 10 involve fire at an airport with CFR and an aircraft damage report of "substantial" rather than "destroyed." These are the only accidents, therefore, in which CFR could have played a role in reducing property damage. The damage prevented in these accidents by CFR is generously estimated to be $5 million over the 5-year period, or $1 million per year; this figure is significantly lower than the $17.871 million per year estimated to be saved by CFR in air carrier hull damage.

3.4 General Aviation Accidents

Even though there are some 1500 general aviation (GA) accidents each year, there is relatively little chance for CFR to provide benefits. There are three main reasons for this. First, many GA accidents are at airports were there is no CFR. Second, because GA aircraft typically have low landing speeds, accidents are often less serious than air carrier accidents. Combining this with the fact that self-evacuation is much easier from a smaller GA aircraft means that there is not much scope for CFR to save lives. Third, since the aircraft are relatively small, if a fire does break out it is likely to engulf the entire aircraft before CFR arrives; this is especially likely since the aviation gasoline used by many GA aircraft catches fire easier and burns faster and hotter than jet fuel. Consequently, it is much harder for CFR to salvage any of the hull in GA accidents. So much for general considerations; now turn to the evidence on human and property loss.

Examination of records to date has not produced an instance of the saving of life or reduction of injury by CFR in a general

aviation accident. Such an accident would have to occur, of course, at a certificated airport or at one of the estimated 100 general aviation airports with CFR. Interviews with personnel at some of the busiest general aviation airports in California revealed no cases of saving of life or property by CFR. The few accidents that did occur at the airports or near them resulted either in all passengers dead on impact or all of them out of the aircraft on arrival of CFR. Based on these findings, the number of lives saved and injuries prevented by CFR in GA accidents is taken to be zero.

Property damage was investigated not only through interviews but also through a computerized analysis of the GA accident tapes compiled by the NTSB. For the years 1973-1975 these tapes were searched for accidents which met four conditions:

(1) the accident was on the airport surface;

(2) there was fire after impact;

(3) ground fire fighting equipment put out the fire;

(4) the aircraft was not totally destroyed.

These four conditions must be met if CFR is to provide a property loss benefit. It was found that virtually no accidents met these conditions. Accordingly, it is assumed that the annual hull savings benefit is $0.1 million for general aviation. This somewhat generous figure is chosen to make sure that benefits are not understated and to allow for possible errors on the accident tapes. It is assumed that these benefits are evenly divided among the

airport indexes. Psychological benefits are assumed to be equal to the total of life/injury benefits for general aviation as well as commuter and air taxi categories. Since there is no life/injury benefit for general aviation, however, there is no psychological benefit, either.

3.5 Non-crash Benefits

Thus far this report has only considered the benefits that CFR provides when responding to an actual crash. However, CFR provides many other services, including fighting structural fires, grass fires, automobile fires, and trash fires, washing down fuel spills, standing by for aircraft emergencies (a crash benefit occurs only if there is a crash), responding to medical emergencies, making fire safety inspections, and performing a host of other functions of an emergency nature. The discussion of these non-crash benefits falls into two areas. First, what non-crash services does CFR provide? Second, how can a dollar value be placed on these services?

First, information on the non-crash services provided was extracted from CFR logs that were inspected during visits to airports of all indexes. By averaging the typical responses at the airports visited, the following response frequencies were derived:

- fuel spill washdowns: 1 per 1000 air carrier departures
- emergency stand-bys: 2 per 1000 air carrier departures
- medical responses: 10 per 1000 air carrier departures
- miscellaneous: 2 per 1000 air carrier departures

The assumption that the level of non-crash services provided is proportional to air carrier activity is justified by the nature of these services. Fuel spill washdowns are performed almost exclusively for air carriers since the more complicated and lengthy process of fueling a large aircraft leaves much more margin for error. Fuel spills involving general aviation aircraft are generally smaller and do not require a washdown by CFR. Emergency stand-bys, although performed for all classes of aviation, are required primarily by air carriers at busy certificated airports. The medical responses are predominantly first aid responses and would correlate strongly with the number of passengers.

Second, a dollar value must be assigned to these non-crash services. The principle followed is to assign to a service what it would have cost to provide that service if there had been no CFR. In other words, the dollar value of a service provided by CFR is the saving that results from the fact that CFR is able to provide that service. If there were no CFR, a fuel washdown would require a single fire truck, while an emergency stand-by would require two fire trucks. Miscellaneous responses are primarily small fires and would also require a single fire truck. Medical responses, it is assumed, would require an ambulance or paramedic.

To determine the cost of these replacement services, a number of fire departments were contacted. No precise figure for the cost can be given, not only because different fire departments have

different charging policies but also because charging for services provided to airports is not something that fire departments currently do. Nevertheless, some quotations have been obtained. For example, the Boston Fire Department charges the Massachusetts Turnpike $500 for responding to a call with one fire truck plus a fire chief. The Fairfax County (Virginia) Fire Department estimates a charge of $277 for a single fast-response vehicle, $651 for two vehicles appropriate for response to an aircraft emergency, and $50 for an ambulance. Since the Fairfax County figures are typical and also broken down into the detail needed, they will be used here. Multiplying the cost per response by the number of occurrences per 1000 air carrier departures, one obtains a total cost of $2633 per 1000 air carrier departures. With 4,771,408 air carrier departures in 1978, excluding Alaska (reference 3.12, Table 2), this gives an annual benefit of $12.563 million per year.

There is still one significant non-crash benefit which has been omitted, however. That benefit was determined to exist only at Atlanta's Hartsfield International Airport, an index D airport, during interviews conducted in the course of the study. Atlanta's medical records, which are kept separate from their CFR logs, show that cardiac technicians, applying defibrillators to heart attack victims, save an average of 17 people per year. Although the victims are transported quickly to hospitals for intensive medical care, the fact remains that thoroughly trained CFR personnel

are responsible for reviving the heart beat of 17 persons every year. Without this service, which is not otherwise conveniently available at the Atlanta airport, the victims would surely die at the airport with no further chance of recovery. On the basis of a $430,000 value for human life, this benefit is $7.310 million per year--much more than enough to pay for CFR at Atlanta. Although similar services are performed at other airports throughout the country by paramedics stationed near the airport, Atlanta was found to be the only major airport which depended solely on its airport-based cardiac technicians. These cardiac specialists should be distinguished from emergency medical tecnologists (EMTs), whose valuable services, which include cardiopulmonary resuscitation (CPR), do not encompass the use of defibrillators.

The total non-crash benefit, therefore, is $19.873 million. This benefit is distributed among the airport indexes according to the percentages in Table 3-10, except that the $7.310 benefit from cardiac technicians is assigned solely to index D. The benefits broken down by index are shown in Table 3-13. It should be emphasized that these figures represent an upper bound on the true non-crash benefits for two reasons. First, it is possible that an airport could find cheaper ways of replacing CFR. For example, for washing down fuel spills, it might be cheaper for an airport to buy an old, outmoded fire truck and use it for nothing else rather than to pay for the fire department's services; or it might be cheaper for the airport to let the fuel spills go unwashed and, thus, to be forced

Table 3-13: Annual Non-Crash Benefits Provided by CFR

AIRPORT INDEX	NON-CRASH BENEFIT (millions)
L	$0.005
A	0.079
AA	0.099
B	0.406
C	2.695
D	11.257
E	5.332
	$19.873

to replace the pavement more frequently. Second, in many cases a local fire department would provide the service without charge. Thus, the non-crash benefits in Table 3-13 are biased in favor of benefits in order to avoid inadvertently understating benefits.

AD-A090 726 FEDERAL AVIATION ADMINISTRATION WASHINGTON DC AIRPOR--ETC F/G 1/5
AIRPORT CRASH/FIRE/RESCUE (CFR) SERVICE COST AND BENEFIT ANALYS--ETC(U)
JUL 80
UNCLASSIFIED FAA-AS-80-2-VOL-1 NL

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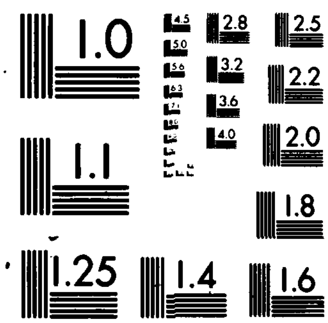
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

3.6 Summary of CFR Benefits

The figures on CFR benefits that have been developed in this chapter will now be brought together and discussed. In order to make these figures comparable, they will be expressed in terms of the average annual benefit. The average annual benefit of CFR broken down by airport index and the category of benefit is shown in Table 3-14. The figures for air carrier crash benefits in this table are obtained by dividing the figures in Tables 3-4, 3-9, and 3-11 by 12 since the tables cover a period of 12 years. (Actually, these tables cover 12 + years since one accident from 1978 is included; thus, benefits here are slightly overstated.) The other figures in this table are taken from sections 3.3, 3.4, and 3.5.

Table 3-14 shows that the estimate of the average annual benefit provided by CFR is $49.202 million. Two conclusions are immediately apparent. First, a relatively small percentage of this benefit comes from saving crash victims. That is, only 10.5 percent of the benefit stems from saving lives of and preventing injuries to passengers in crashes. Even if the psychological benefits are included, still only 21.0 percent of the benefits are attributable to preventing human loss in crashes; 79.0 percent of the benefits comes from saving hulls and from the non-crash services provided by CFR. Thus, even though discussions of CFR are usually couched in terms of how many lives

Table 3-14: Annual Benefits of CFR (millions of dollars)

	AIRPORT INDEX								
	L	A	AA	B	C	D	E	TOTAL	
Air Carrier Crash Benefits									
Property	0.000	0.100	0.000	0.000	2.333	4.004	11.433	17.871	(36.3%)
Lives/Injuries	0.000	0.000	0.036	0.000	0.179	0.000	4.764	4.979	(10.1%)
Psychological	0.002	0.031	0.039	0.161	1.068	1.564	2.113	4.979	(10.1%)
Commuter and Air Taxi Crash Benefits									
Property	0.143	0.143	0.143	0.143	0.143	0.143	0.143	1.000	(2.0%)
Lives/Injuries	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.200	(0.4%)
Psychological	0.000	0.001	0.002	0.006	0.043	0.063	0.085	0.200	(0.4%)
General Aviation Crash Benefits									
Property	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.100	(0.2%)
Lives/Injuries	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(0.0%)
Psychological	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(0.0%)
Non-Crash Benefits	0.005	0.079	0.099	0.406	2.695	11.257	5.332	19.873	(40.4%)
Total	0.193	0.397	0.362	0.759	6.504	17.074	23.913	49.202	
	(0.4%)	(0.8%)	(0.7%)	(1.5%)	(13.2%)	(34.7%)	(48.6%)		

NOTE: Components may not add to totals due to rounding

are saved, in dollar terms the hull savings and the non-crash benefits are three times as important.

Second, the lion's share of the benefits accrues to larger airports; 48.6 percent of benefits occurs at index E airports, 34.7 percent at index D airports, 13.2 percent at index C airports, and a total of 3.4 percent at airports of indexes L, A, AA, and B.

Discussion of the relationship between these benefits and the CFR costs derived in Chapter 2 is postponed until Chapter 6.

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4.0 CFR COST PROJECTION

4.1 The Methodology for Projecting CFR Costs

From the information about current CFR costs appearing in Chapter 2 and from information about the future, it is possible to project CFR costs into the future. This chapter first presents a general methodology that can be used to perform this projection and then performs the projection for a sample scenario.

Before giving the details of the methodology, a number of variables must be defined. For purposes of CFR, each airport is assigned an index based on the character of its traffic, as explained in Chapter 1. Let i stand for the index of an airport. For the Indexes E, D, C, B, AA, A, L (Limited), and NC (non-certificated), let i take on the values 1, 2, 3, 4, 5, 6, 7, and 8, respectively.

CFR expenditures can be divided into four categories:

1) manpower expenditure;
2) vehicles;
3) building expenditure;
4) equipment and materials.

Let e stand for the expenditure category, and let e take on the values 1, 2, 3, and 4 for these four categories of expenditure, respectively.

We want to allow for the possibility that CFR costs, especially for manpower, depend on the region of the country in which the airport is located. Let there be four regions, and let g stand for the region in which an airport is located, g=1, 2, 3, or 4.

We want to project the CFR costs at an airport for each of the next 15 years. Therefore, let t stand for the year, where t takes on one of the values 1, 2, ..., 15.

It is next necessary to define three functions. We distinguish airports by index and geographical region but not in any other way. Thus, given the index and geographical region, we deal only with an average airport. Let c(i,e,g,t) be the average expenditure on items of class e at an airport of index i located in geographical region g in year t. This cost is expressed in real dollars, i.e., in constant dollars that have been corrected for inflation. In order to make it easier to specify values for this cost function, it is assumed that the annual rate of increase in the real expenditure for each expenditure category is constant over time. However, this rate of increase is allowed to vary by expenditure category and by geographical region. Let r(e,g) be the annual rate of increase of the real price of items in expenditure category e in geographical region g. It is true that this rate of increase will probably vary from year to year; however, these yearly fluctuations are very difficult to forecast, so the assumption of a constant annual rate is probably

most suitable for purposes of projection.

We can now write $c(i,e,g,t)$ as

$$c(i,e,g,t) = c(i,e,g,1) \times \left[1 + r(e,g)\right]^{t-1} \qquad (4.1)$$

That is, once the function $r(e,g)$ is specified, it is only necessary to specify $c(i,e,g,t)$ for the first year; all other years can then be calculated. That is, once the costs in the first year and the annual rate of increase of costs is known, then the costs for every year can be calculated. This is a valuable property for the methodology to have because it greatly reduces the data requirements.

This formulation assumes that, given an index and a region, airports purchase the same quantity of each expenditure category over time. That is, each year the same number, for example, of firemen are employed. Thus, the increase in manpower cost is due to an increase in real wages, not to an increase in the number of men employed.

It is necessary to know how many airports there are with CFR. Let $n(i,g,t)$ be the number of airports of index i located in geographical region g in year t.

These definitions imply that the total cost of the nation's CFR in year t, symbolized by $C(t)$, is given by

$$C(t) = \sum_{i=1}^{8} \sum_{g=1}^{4} \left[n(i,g,t) \sum_{e=1}^{4} c(i,e,g,t) \right] \tag{4.2}$$

Using equation (4.1), (4.2) can be written as

$$C(t) = \sum_{i=1}^{8} \sum_{g=1}^{4} \left[n(i,g,t) \sum_{e=1}^{4} \left[c(i,e,g,1) x \left[1 + r(e,g) \right]^{t-1} \right] \right] \tag{4.3}$$

Therefore, equation (4.3) embodies the projection methodology. If one specifies values for

- $c(i,e,g,1)$ for all values of i,e, and g,
- $r(e,g)$ for all values of e and g, and
- $n(i,g,t)$ for all values of i,g, and t,

then equation (4.3) can be used to project the nation's CFR cost for every year.

4.2 Projecting CFR Cost for a Sample Scenario

In order to illustrate how the projection methodology just explained can be applied, CFR costs will be projected for a sample scenario. Two simplifying assumptions are used. First, it is assumed that costs are the same in different regions. Second, it is assumed that the number of airports in each index is constant over time. These two assumptions imply that the level of CFR services provided is constant over time. Also, these assumptions imply that the functions $c(i,e,g,1)$, $r(e,g)$,

and n(i,g,t) can be simplified to c(i,e,1), r(e), and n(i).

Equation (4.3) can now be written in the form

$$C(t) = \sum_{e=1}^{4}\left[\left[1 + r(e)\right]^{t-1} \sum_{i=1}^{8} n(i)\, c(i,e,1)\right] \tag{4.4}$$

which is handiest for calculation.

The first task is to determine values for r(e), the annual rate of increase in the real price of items in expenditure category e. The method used is as follows. For each expenditure category obtain a price index and determine the rate of increase in the price of that expenditure category (not corrected for inflation) over the last 5 or 10 years. From this rate of increase subtract the average rate of inflation over the same time period; the difference is the real rate of increase of the price of items in this category in the past. Finally, assume that the future real rate of price increase stays the same in the future. This gives the desired value for r(e). Now consider each expenditure category.

Manpower. A publication of the Bureau of Labor Statistics (Ref. 4.1) shows that over the years 1973-1978 the average rate of increase in firemen's wages was 6.4 percent (p. 4). This figure is obtained by averaging all regions together and by averaging together firemen of different levels of experience.

It is assumed that the wage experience of CFR firemen is the same as firemen in general, at least insofar as wage increases are concerned. The annual rate of increase of the consumer price index for the relevant years is also 6.4 percent. The conclusion, therefore, is that the real cost of CFR manpower is constant over time, i.e., r(1)=0.0.

Looking ahead to further study, it should be noted that the publication cited does break the data down according to region of the country and city size, so the manpower cost projections could be tailored more closely to the specific situation of each airport.

Vehicles. Discussion with a vice-president of the Walter Motor Truck Company indicates that the cost of CFR vehicles is tracked reasonably well by the General Purpose Tactical Vehicle Index compiled by the Bureau of Labor Statistics. From 1967 to 1977 this index increased at an annual rate of 7.2 percent. Over this period the consumer price index increased at an annual rate of 6.1 percent. Therefore, the real annual increase in the cost of CFR vehicles is 1.1 percent, i.e., r(2)=0.011.

Buildings. The Bureau of Labor Statistics compiles no index on construction cost because of the non-substitutability of different buildings, but indexes do exist on the cost of construction materials and construction labor (Ref. 4.2, pp. 225, 246). In the ten-

year period starting in 1967, the rate of increase in labor costs was 6.7 percent per year; the rate of increase of the price of construction materials was 7.3 percent per year. Using the rule of thumb that 80 percent of the cost of a building goes for labor and 20 percent for materials, we take the weighted average of 6.7 and 7.3 percent to obtain 6.8 percent as the annual rate of increase of the price of CFR buildings, i.e.,

$$0.068 = (0.80 \times 0.067) + (0.20 \times 0.073).$$

Since the annual rate of inflation over these years was 6.1 percent, the real expenditure on buildings went up by 0.7 percent per year, i.e., $r(3)=0.007$.

<u>Equipment and Materials</u>. Since this category contains a variegated assortment of items, the most natural assumption is that the price of items in this category goes up with the rate of inflation, i.e., $r(4)=0.0$.

The information needed to project CFR cost for the country has now been assembled and the projected cost can be calculated. Since the number of airports in each index is constant over time and since there is no variation among geographical regions, we need only deal with the aggregate national cost for each expenditure category and need not deal with each index separately; this can be seen by examining equation (4.4). Thus, we do not need to know $n(i)$ as long as we know the aggregate national cost for

each expenditure category, and we know this from Chapter 2.

The first row in Table 4-1 shows the current national cost for each expenditure category; this is from Chapter 2. Since r(1)=0.0 and r(4)=0.0, the manpower cost and the equipment and materials cost are constant over time. Since r(2)=0.011, the vehicle cost increases by 1.1 percent per year; these costs are shown in Table 4-1. Since r(3)=0.007, the buildings cost increases by 0.7 percent per year; these costs also are shown in Table 4-1. Adding each row of this table gives C(t), the projected real cost of CFR in year t. As the reader can verify, this calculation has been done in accordance with equation (4.4). It is seen that in this sample scenario the annual **real** cost of CFR 15 years hence is projected to be roughly *$2.8 million dollars* greater than at present. This completes the projection for the sample scenario.

Table 4-1: Projected CFR Costs Under the Sample Scenario (Thousands of 1979 Dollars)

Year	Manpower	Vehicles	Buildings	Eqpt. & Mat.	Total
1	$91,801	$12,631	$7,192	$3,697	$115,321
2	91,801	12,770	7,242	3,697	115,510
3	91,801	12,910	7,293	3,697	115,701
4	91,801	13,052	7,344	3,697	115,894
5	91,801	13,196	7,396	3,697	116,090
6	91,801	13,341	7,447	3,697	116,286
7	91,801	13,488	7,499	3,697	116,485
8	91,801	13,636	7,552	3,697	116,686
9	91,801	13,786	7,605	3,697	116,889
10	91,801	13,938	7,658	3,697	117,094
11	91,801	14,091	7,712	3,697	117,301
12	91,801	14,246	7,766	3,697	117,510
13	91,801	14,403	7,820	3,697	117,721
14	91,801	14,561	7,875	3,697	117,934
15	91,801	14,722	7,930	3,697	118,150

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5.0 CFR BENEFIT PROJECTION

5.1 The Methodology for Projecting CFR Benefits

From the information about current and past CFR appearing in Chapter 3 and from information about the future, it is possible to project CFR benefits into the future. This chapter first presents a general methodology that can be used to perform this projection and then performs the projection for a sample scenario.

The projection of CFR benefits involves four components:

1. projecting air carrier crash benefits;
2. projecting commuter and air taxi crash benefits;
3. projecting general aviation crash benefits;
4. projecting non-crash benefits.

Each of these components will now be considered.

In order to project air carrier crash benefits, it is necessary to define five functions. Let n(i,d,h,t) be the expected number of accidents per 100 million air carrier operations in year t at airports of Index i such that CFR prevents exactly d deaths and saves exactly h hulls in each of these accidents. This definition of n(i,d,h,t) is used to make it easier to assess this function; there were roughly 100 million operations in the period covered by the data search described in Section 3.2.1. (Note:

This function should not be confused with the function in Chapter 4 also symbolized by n.) Second, let OPS(i,c,t) be the number of class c operations (air carrier, commuter/air taxi, general aviation) at airports of Index i in year t. Third, let $V_D(t)$ be the value assigned to preventing a death in year t. Fourth, let $V_I(t)$ be the value assigned to preventing an injury in year t. Fifth, let $V_H(t)$ be the value of the average hull in year t.

Note that

$$\frac{n(i,d,h,t)}{100 \text{ million}}$$

is the probability that any one air carrier operation at an Index i airport in year t leads to an accident in which CFR saves exactly d deaths and h hulls, and

$$OPS(i,AC,t) \times \frac{n(i,d,h,t)}{100 \text{ million}}$$

is the expected number of these accidents. "AC" refers to air carrier operations. The variable d would take on values 0, 1, 2, ... The variable h might take on values like 0, 0.1, 0.2, 0.3, ...

Using the data in Chapter 3 as a guide, assume that the number of injuries prevented by CFR can be derived by dividing the number of deaths prevented by 3. Then if d deaths are prevented and h hulls are saved in year t, the value of this is

$$d\,V_D(t) + (d/3)\,V_I(t) + h\,V_H(t).$$

This means that the total air carrier crash benefit of CFR in year t, symbolized by ACCB(t), is given by the equation

$$ACCB(t) = \sum_i \sum_d \sum_h \frac{OPS(i,AC,t) \times n(i,d,h,t)}{100 \text{ million}} \left[dV_D(t) + \frac{d}{3}V_I(t) + hV_H(t) \right]$$

$$+ \alpha \sum_i \sum_d \sum_h \frac{OPS(i,AC,t) \times n(i,d,h,t)}{100 \text{ million}} \left[dV_D(t) + \frac{d}{3}V_I(t) \right] . \quad (5.1)$$

The first term in this equation represents the expected value of the lives, injuries, and hulls actually saved; the second term represents the psychological benefit. α is the constant defined in Section 3.2.4. For example, if $\alpha = 1$, then the psychological benefit equals the expected value of lives saved and injuries prevented.

In summary, equation (5.1) is the suggested methodology for projecting the air carrier crash benefits. When values have been specified for the five functions and for α, then the projected CFR air carrier crash benefits for the year t can be calculated.

Thus, the problem of projecting CFR air carrier crash benefits has been reduced to the problem of specifying the five functions. Some of the subtleties involved in specifying these functions will first be discussed and then some methods for specifying them.

Specifying the five functions is somewhat tricky because they are affected by a number of factors that lie behind the scenes and have not been mentioned so far. For example, consider $n(i,d,h,t)$. The number of accidents in which 100 lives are saved clearly depends on the fleet mix; the higher the number of high-capacity aircraft, the greater the chance that there will be an accident in which a large number of lives will be saved. Moreover, fleet mix can also affect this function if different aircraft have different accident potentials. Also, technology enters into this function; as electronic landing systems and other instrumentation improve, the expected number of accidents will decline. Also, as load factors increase, possibilities for accidents which yield larger CFR benefits increase.

The function $V_D(t)$ that gives the value of a life in year t is not necessarily constant, even after the effects of inflation are removed. For example, it is generally thought that the value of saving a life goes up as real income goes up, so any changes in

the nation's per capita real income are likely to change $V_D(t)$ and also $V_I(t)$. Moreover, if deregulation proceeds and leads to a changed composition of the passengers on aircraft, then this could change the per capita income of the people whom CFR potentially saves, and this would change $V_D(t)$ over time.

The function $V_H(t)$ which gives the value of an average hull will depend on what technology and on what future generations of airplanes look like. Moreover, fleet mix will obviously have an effect on the value of the average hull.

In short, each of the five functions that must be specified depends on a host of complicated factors which can be predicted only with difficulty and which, even if predicted accurately, have uncertain effects. In light of this, how might one go about specifying these five functions? Two approaches deserve comment.

First, there is the naive approach. This approach assumes that the future will in most ways be like the past. For example, it might be assumed that the functions $n(i,d,h,t)$, $V_D(t)$, $V_I(t)$, and $V_H(t)$ remain unchanged over the next fifteen years; the only change that is recognized is that the number of operations OPS(t) will be increasing over time. This naive approach suffers from two difficulties. The first difficulty is that the future probably will not be like the past. There will probably be changes in technology, fleet mix, load factors, per capita income, and other

factors. The naive approach goes astray by ignoring the fact that the past is but an imperfect guide to the future. The second difficulty is that our knowledge of the past is limited by the small sample. That is, out of some 100 million operations, only one of them led to an accident that allowed CFR to save 100 lives. Perhaps this crash was a fluke and there will not be another like it for another fifty years; or perhaps there will be two like it next year. With such a small sample, one cannot draw precise conclusions. Thus, since there is doubt about what the past was like, even if the future is like the past, one can say only approximately what the future will be like. The naive method, then, has its drawbacks.

The second method for specifying the five functions is to use the subjective approach. The idea behind this approach is that the best way to process all this vague and incomplete information is in the mind of a knowledgeable person. Even though the past is not a perfect guide to the future, it is still a guide of sorts. A knowledgeable person combines in his mind this information about the past with what he knows about what might happen in the future. This person is then interrogated by a decision analyst in order to force him to put all this information into the form of the needed functions. (The basic references on this interrogation process are Refs. 5.1 and 5.2.) This method, while not foolproof, does seem to promise to give the best specifications for the five functions needed in order to project CFR

benefits. This method would probably be a worthwhile approach to try in future work.

It is assumed that commuter and air taxi crash benefits in year t, symbolized by CATCB(t), are proportional to the number of operations. Therefore, we project these benefits with the equation

$$\mathrm{CATCB}(t) = \frac{\sum_i \mathrm{OPS}(i,\mathrm{CAT},t)}{\sum_i \mathrm{OPS}(i,\mathrm{CAT},1)} \times \mathrm{CATCB}(1). \quad (5.2)$$

That is, $\sum_i \mathrm{OPS}(i,\mathrm{CAT},t)$ is the total number of commuter and air taxi operations in year t, and $\sum_i \mathrm{OPS}(i,\mathrm{CAT},1)$ is the total number of commuter and air taxi operations in year 1. Therefore, the ratio of these two quantities in equation (5.2) is the proportional increase in commuter and air taxi operations in year t relative to year 1. What equation (5.2) says, then, is that if in year t the number of commuter and air taxi operations is, say, 10 percent larger than in year 1, then the commuter and air taxi crash benefits in year t are also 10 percent larger than in year 1. The rationale for the proportionality assumption, both here and in the next paragraph, is that the factors that disturb proportionality in the case of air carriers (e.g., changes in technology, aircraft size, load factors) are much less important for commuter, air taxi, and general aviation.

It is similarly assumed that general aviation crash benefits in year t, symbolized by GACB(t), are proportional to the number of operations. Therefore, we project these benefits with the equation

$$\mathrm{GACB}(t) = \frac{\sum_i \mathrm{OPS}(i,\mathrm{GA},t)}{\sum_i \mathrm{OPS}(i,\mathrm{GA},1)} \times \mathrm{GACB}(1). \tag{5.3}$$

The interpretation of equation (5.3) is analogous to that of (5.2).

Finally, it is assumed that non-crash benefits are proportional to the number of air carrier operations. Air carrier operations are used since most of the non-crash benefits stem from air carrier operations (e.g., stand-bys, fuel spills) or from the needs of air carrier passengers (e.g., medical emergencies). The equation used to project non-crash benefits for year t, symbolized by NCB(t), is

$$\mathrm{NCB}(t) = \frac{\sum_i \mathrm{OPS}(i,\mathrm{AC},t)}{\sum_i \mathrm{OPS}(i,\mathrm{AC},1)} \times \mathrm{NCB}(1). \tag{5.4}$$

In summary, the total CFR benefits in year t, symbolized by B(t), are given by adding up the four components, i.e.,

$$B(t) = \mathrm{ACCB}(t) + \mathrm{CATCB}(t) + \mathrm{GACB}(t) + \mathrm{NCB}(t). \tag{5.5}$$

The proposed methodology embodied in equations (5.1) - (5.5) should be thought of not as a cookbook which yields a projection if a set of instructions is mechanically followed. Rather, this methodology serves as a framework for making a projection; it identifies the crucial information that is needed, but it leaves to the analyst the details of how this information is generated.

5.2 Projecting CFR Benefits for a Sample Scenario

In order to show how equations (5.1) - (5.5) can be used to project CFR benefits, a projection will now be carried out for a sample scenario. The projection will be for the nation as a whole and not be broken down according to indexes. Thus, the variable i is dropped from all equations. The five functions required by the projection will now be specified. It should be emphasized that since this projection is only illustrative, it has been deemed sufficient to make these specifications plausible, and it has not been thought necessary to do a full-blown study of these specifications. Thus, this projection shows how to use equations (5.1) - (5.5), but there is no pretense that the specific numbers projected are reliable enough for policy-making purposes.

First, consider the function n(d,h,t), which gives for 100 million operations the expected number of accidents in which CFR would prevent exactly d deaths and save h hulls in year t. Specifying this function is the heart of the projection and is the most difficult part. The method to be used to specify this function is to examine the data on benefits over the period 1966-1978 described in Chapter 3 and to try to envision the stochastic process that generated these data.

The 42 accidents that provided CFR benefits from 1966 to 1978 are in Table 5-1 divided up according to how many deaths were prevented and how much of the hull was saved in each. This period contained roughly 100 million operations. For example, this table says there was exactly one accident in this time period in which CFR saved from 3 to 7 lives and also saved from 61 to 80 percent of the hull. The hypothesis is advanced that, given the number of deaths prevented in an accident, that accident has an equal chance of falling into any one column. If one looks at the last five rows, this hypothesis appears reasonable, since the numbers are scattered fairly evenly among the columns. However, the number of accidents in the first row is not evenly spread. The assumption made here is that these numbers would have been equally spread except for sample variation. (To understand this last remark, consider an example of sample variation. Suppose a coin is flipped 10 times; then one expects to get 5 heads. However, the actual number of heads that come up

Table 5-1: Breakdown of Air Carrier Accidents by the Number of Deaths Prevented and the Number of Hulls Saved by CFR, 1966-1978

		Percentage of Hull Saved					
		0	1-20	21-40	41-60	61-80	81-100
Deaths Prevented	0	0	14	3	4	6	10
	1-2	1	0	0	0	0	0
	3-7	0	0	0	0	1	0
	8-10	1	0	0	0	0	0
	11-30	0	0	0	0	1	0
	90-100	0	0	1	0	0	0

might well be different from 5; this difference is termed sample variation.)

The "pure" form of Table 5-1, purged of sample variation, is shown in Table 5-2, which is assumed to be the relevant table for 1979. The ranges that define the cells have been replaced by typical numbers. Since the first row contains 37 accidents and there are five relevant columns, each cell in the first row has an expected number of accidents of 37/5 = 7.4. Each of the other rows contains one accident and six relevant columns, so each cell has an expected number of accidents of 1/6. For example, in the third row of Table 5-1 there was one accident, and it is assumed that it had an equal probability of falling in any column; column five is the one it happened to fall in.

It might be objected that the hypothesis of equal probability advanced here is not the only hypothesis that can explain Table 5-1. This objection is correct, but not too important. It is not claimed that this is the only possible hypothesis; all that is claimed is that it satisfactorily fits the data and is suitable for this sample projection. It might be objected that this table overstates the benefits, since there has been a downward trend in the number of accidents. However, in reply it should be pointed out that the number of people exposed to CFR-relevant accidents has stayed roughly the same over time (see Figure 3-4). In summary, while no iron-clad

Table 5-2: Hypothesized Breakdown of Air Carrier Accidents by the Expected Number of Deaths Prevented and Number of Hulls Saved by CFR per 100 Million Operations for Year 1

		Percentage of Hull Saved					
		0	10	30	50	70	90
Deaths Prevented	0	0.00	7.40	7.40	7.40	7.40	7.40
	1	0.17	0.17	0.17	0.17	0.17	0.17
	5	0.17	0.17	0.17	0.17	0.17	0.17
	9	0.17	0.17	0.17	0.17	0.17	0.17
	20	0.17	0.17	0.17	0.17	0.17	0.17
	100	0.17	0.17	0.17	0.17	0.17	0.17

case can be built for Table 5-2, it is argued that it is plausible to assume that this table describes the state of things in 1979. (Since there will be roughly 10 million operations in 1979, numbers in Table 5-2 should be divided by 10 to give the number of accidents in each class expected to occur in 1979.)

Now that the n(d,h,t) function has been specified for 1979, it is necessary to specify how this function changes over time. It will be assumed that, for given values of d and h, this function decreases by 1 percent per year. The basis for this assumption is that some increases in safety are expected in coming years. Such an assumption is believed to be plausible. Thus, the function n(d,h,t) is written

$$n(d,h,t) = \begin{cases} 7.40\ (1.01)^{1-t} & \text{if } d=0 \text{ and } h\neq 0 \\ 0.17\ (1.01)^{1-t} & \text{if } d\neq 0 \end{cases}$$

We need not define n(d,h,t) for d=h=0, since, in this case, the CFR benefit is 0. Note that d is only allowed to take on the values 0, 1, 5, 9, 20, and 100. Of course, it is possible that there would be an accident in which CFR would save some other number of lives, but it is assumed that for modeling purposes these four possible values are sufficient to describe all likely accidents with sufficient accuracy. This completes the specification of the n(d,h,t) function.

Second, consider the function OPS(c,t), which gives the number of operations in year t for the three classes of operations. The assumed values for this function are shown in Table 5-3. The values for years 1-12 are the FAA forecasts for 1979-1990 (Ref. 5.3, p. 66). The values for years 13-15 are obtained by assuming that the number of operations past year 12 increases by 2.1 percent per year for air carriers, 7.6 percent per year for air taxi and commuters, and 3.5 percent per year for general aviation; these rates of growth are taken from the FAA forecast (Ref. 5.3, p. 10).

Third, consider the function $V_D(t)$, which is the value of preventing a death in year t. It is assumed that every year this function takes on the 1979 value of $430,000 used above in Section 3.2.4. (Recall that this amount is in constant dollars.)

Fourth, consider the function $V_I(t)$, which is the value of preventing an injury in year t. It is assumed that in every year this function takes on the 1979 value of $64,000.

Fifth, consider the function $V_H(t)$, which gives the value of the average hull in year t. Since larger planes are replacing smaller and since planes are being equipped with more expensive avionics, it is clear that the value of the average hull should be rising every year. It is assumed that $V_H(t)$ increases by 2.5 percent every year, with a 1979 value of $8.5 million. Table 5-4 shows the resulting average hull values.

Table 5-3: Assumed Values for OPS(c,t)

t	Air Carrier Operations (Millions)	Air Taxi & Commuter Operations (Millions)	General Aviation Operations (Millions)
1	10.4	4.0	29.8
2	10.7	4.4	31.7
3	10.9	4.9	33.5
4	11.1	5.3	35.4
5	11.4	5.7	36.7
6	11.6	6.3	37.8
7	11.8	6.7	39.0
8	12.0	7.1	40.0
9	12.3	7.5	40.9
10	12.5	7.9	41.7
11	12.7	8.1	42.5
12	12.9	8.4	43.2
13	13.2	9.0	44.7
14	13.4	9.7	46.3
15	13.7	10.5	47.9

Table 5-4: Assumed Values for the Average Hull

Year	Value of Average Hull (Millions of Dollars)
1	8.500
2	8.712
3	8.930
4	9.154
5	9.382
6	9.617
7	9.857
8	10.104
9	10.356
10	10.615
11	10.881
12	11.153
13	11.432
14	11.717
15	12.010

The constant α, which is used in determining the psychological benefit is taken to be equal to 1, as in Section 3.2.4

The sample scenario is completed by assuming 1979 values for commuter and air taxi benefits, general aviation benefits, and non-crash benefits. The values assumed, based on Chapter 3, are

$$\text{CATCB}(1) = \$1.2 \text{ million}$$

$$\text{GACB}(1) = \$0.1 \text{ million}$$

$$\text{NCB}(1) = \$18.3 \text{ million}$$

All information needed to project benefits has now been specified. To repeat, there is no compelling argument that the future will necessarily be in accord with the assumptions made here; nevertheless, it is plausible that it will. This, it is claimed, justifies the use of this sample scenario. All that remains is to substitute this information into equations (5.1) - (5-5) and to perform the required calculations.

Table 5-5 shows the projections for each component of air carrier crash benefits for the years 1979-1993. It is seen that the fall in the annual number of accidents is more than offset by the increases in hull values and in the number of operations, so the total air carrier crash benefit increases steadily over the years. The bulk of this increase is due to increases in the value of hulls saved; this source provides $11.265 million of the total increase in crash benefits of $13.091 million. The increase in human benefits is only $1.826 million.

Table 5-5: Projection of Air Carrier Crash Benefits, 1979-1993 (Millions of Dollars)

Year	Hull Saved	Lives Saved	Injuries Prevented	Psychological Benefits	TOTAL
1979	18.199	6.049	0.300	6.349	30.897
1980	18.999	6.148	0.305	6.453	31.905
1981	19.636	6.189	0.307	6.496	32.628
1982	20.301	6.263	0.311	6.574	33.449
1983	21.153	6.353	0.315	6.668	34.489
1984	21.854	6.424	0.319	6.743	35.340
1985	22.553	6.453	0.320	6.773	36.099
1986	23.271	6.479	0.321	6.800	36.871
1987	24.250	6.574	0.326	6.900	38.050
1988	24.965	6.618	0.328	6.946	38.857
1989	25.752	6.679	0.331	7.010	39.772
1990	26.539	6.694	0.332	7.026	40.591
1991	27.566	6.804	0.338	7.142	41.850
1992	28.387	6.814	0.338	7.152	42.691
1993	29.464	6.919	0.343	7.262	43.988

Table 5-6 shows the projection for total CFR benefits over the years 1979-1993, rising gradually from $50.497 million in 1979 to $71.406 million in 1993, an average annual rate of increase of 2.7 percent. Of this $20.909 million increase, $13.091 million is due to the increase in air carrier crash benefits, and $5.807 million is due to the increase in non-crash benefits.

A lesson one learns from this projection is that the bulk of the increase in benefits is due to the increase in air carrier crash benefits, and the main reason why air carrier crash benefits increase so much is that the value of the average hull is assumed to increase by 2.5 percent per year. Therefore, the assumed rate of increase of the value of the average hull is a key assumption that should be treated with great care in any future study.

In summary, the projection of CFR benefits for the sample scenario is now complete. It has been shown how the equations (5.1) - (5-5) can be specified and how the methodology can be applied to project benefits.

Table 5-6: Projection of Benefits Provided by CFR, 1979-1993 (Millions of Dollars)

Year	Air Carrier Crash Benefits	Commuter & Air Taxi Crash Benefits	General Aviation Crash Benefits	Non-Crash Benefits	Total
1979	30.897	1.200	0.100	18.300	50.497
1980	31.905	1.320	0.106	18.828	52.159
1981	32.628	1.470	0.112	19.180	53.390
1982	33.449	1.590	0.119	19.532	54.690
1983	34.489	1.710	0.123	20.060	56.382
1984	35.340	1.890	0.127	20.412	57.769
1985	36.099	2.010	0.131	20.763	59.003
1986	36.871	2.130	0.134	21.115	60.250
1987	38.050	2.250	0.137	21.643	62.080
1988	38.857	2.370	0.140	21.995	63.362
1989	39.772	2.430	0.143	22.347	64.692
1990	40.591	2.520	0.145	22.699	65.955
1991	41.850	2.700	0.150	23.227	67.927
1992	42.691	2.910	0.155	23.579	69.335
1993	43.988	3.150	0.161	24.107	71.406

References

5.1 Raiffa, Howard, Decision Analysis, Addison-Wesley, 1968.

5.2 Keeney, Ralph and Howard Raiffa, Decisions with Multiple Objectives: Preferences and Value Tradeoffs, Wiley, 1976.

5.3 FAA Aviation Forecasts: Fiscal Years 1979-1990, U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Policy, U.S. Government Printing Office, September 1978.

6.0 SUMMARY: THE COSTS AND BENEFITS OF CFR

The information on the costs and benefits of CFR developed in Chapters 2 and 3 will be analyzed in order to bring out the main features of the CFR program. Table 6-1 contains the basic information. The first row shows the annual cost of CFR, broken down by airport index; these figures come from Table 2-8. The second row shows the average annual benefit of CFR; these figures come from Table 3-14. The third row, the benefit/cost ratio, is obtained by dividing the second row by the first. An entry in this row, e.g. 0.84 for index D airports, means that $0.84 in benefits are received for every dollar spent on CFR. The last row shows the net costs and is obtained by subtracting the second row from the first; this shows the amount by which costs exceed benefits. The results appearing in this table will be analyzed by answering eight questions.

1. <u>What are the benefit/cost ratios</u>? It is seen that the benefit/cost ratios in Table 6-1 are, except for indexes D and E, quite low and in some cases astoundingly low. For all indexes together, one dollar spent on CFR provides, on average, $0.43 of benefits. It is only for index E airports that the benefit/cost ratio is greater than one; index D is the only other index that is even close.

2. <u>What bias is there in these benefit/cost ratios</u>? Insofar as these benefit/cost ratios are inaccurate, they are probably

Table 6-1: CFR Average Annual Benefits, Costs, Benefit/Cost Ratios, and Net Costs

	AIRPORT INDEX								
	NC	L	A	AA	B	C	D	E	TOTAL
Costs (millions)	$1.393	1.842	7.825	7.058	12.411	42.111	20.313	22.368	$115.321
Benefits (millions)	$0.000	0.193	0.397	0.362	0.759	6.504	17.074	23.913	$ 49.202
Benefit/ Cost Ratio	0.00	0.10	0.05	0.05	0.06	0.15	0.84	1.07	0.43
Net Costs (millions)	$1.393	1.649	7.428	6.696	11.652	35.607	3.239	-1.545	$ 66.119

too high. Throughout this report, whenever a choice had to be made as to how benefits were to be measured, the choice that made benefits larger was taken. For example, it was assumed that psychological benefits equal the value of deaths and injuries prevented, that 10 percent of a hull is saved when a runway is foamed, and that a wheel well fire, if unextinguished, would have destroyed the entire aircraft. Moreover, generous amounts were assigned for commuter and air taxi benefits, for general aviation benefits, and for non-crash benefits. Thus, every attempt has been made to ensure that the estimates of the benefit/cost ratios that appear in Table 6-1 are upper bounds of the true values. Thus, even if it turns out that an accident or two have been missed in enumerating benefits, one can have confidence that these benefit/cost ratios do not seriously understate benefits.

3. What policy conclusions can immediately be drawn? None. Table 6-1 provides the basic information about CFR, but further analysis would be necessary before arriving at a policy recommendation. This can be seen by considering the policy recommendation that a CFR advocate and a CFR opponent might make, based on these figures.

CFR Advocate:

> The small benefit/cost ratios stem from the fact that airports have inadequate CFR. The FAA should require more effective CFR - greater quantity of extinguishing agent, lower response times, and more rapid intervention

vehicles. Only in this way can the true potential of CFR be exploited.

CFR Opponent:

The small benefit/cost ratios show the CFR just does not do the job. Except at the larger airports there are not enough CFR-relevant accidents to justify these vast expenditures on CFR. The FAA, therefore, should make CFR voluntary and give airports the option of spending the money on other safety programs that would be more effective.

Thus, two opposite policy recommendations can be based on the figures in Table 6-1. However, determining which, if either, of these recommendations is desirable requires further analysis. What would be the effect of additional CFR requirements? What alternate safety programs might CFR money be spent on? Further work under the contract under which this report is written will consider policy alternatives; it must be stressed that the information contained in this report alone is not sufficient for recommending policies.

4. <u>To what extent should CFR be judged on a dollars and cents basis</u>? This report has attempted to measure the desirability of the CFR program in dollars. However, it can be argued that intangibles are involved and that CFR, like freedom of the press, should not be judged solely on a dollars-and-cents basis. In

order to make clear what is at issue, consider the three steps involved in judging the CFR program in terms of dollars:

- state the anticipated consequences of the program;
- assign a dollar value to each anticipated consequence;
- add up the dollar values to obtain a dollar measure of the desirability of that program.

Three general objections can be raised to the dollar valuation of the decision.

1) Some of the consequences have been forgotten.
2) It is not possible to assign a dollar value to some consequences.
3) The wrong dollar value has been assigned to some consequences.

The relevance of each of these potential objections to the question of whether CFR should be judged solely on the basis of dollars and cents will now be discussed. Objection 1 is not relevant, since, if one has forgotten the consequence, this damages not only the dollar valuation of CFR but also any other, less quantitative, valuation. Objection 3 is not relevant, since, as will be shown below, the results are not sensitive to the particular dollar values assigned. Objection 2 is relevant <u>if</u> anyone can think of a significant, intangible

consequence of CFR that has been omitted. H H Aerospace has not been able to think of such a consequence; therefore, provisionally it will be assumed that no such consequence exists. Thus, the tentative conclusion is that there is no objection to judging CFR solely on a dollars-and-cents basis. If anyone disagrees with this, the burden of proof is on him to show that there is a significant consequence of CFR to which no dollar value has been assigned.

5. <u>What is the CFR cost per enplaned passenger</u>? If we divide the annual cost of CFR of $115.321 million by the number of enplaned passengers for 1978 of 262.335 million (Table 3-10), then it is seen that the system-wide average CFR cost per enplaned passenger is $0.44. That is, every time a passenger gets on an air carrier, $0.44 is spent on CFR. If we consider the net cost of CFR from Table 6-1, the system-wide average net cost per enplanement is $0.25 That is, of the $0.44 spent on CFR for the average passenger, $0.19 returns as benefit, but $0.25 is not recovered, and there is no corresponding benefit.

6. <u>What is the payoff per million dollars spent on CFR</u>? The meaning of the figures in the previous paragraph is somewhat difficult to grasp intuitively; $0.25 is a small amount of money, but is it large when compared to the exceedingly small

probability of a passenger being involved in an accident where CFR provides a benefit? To avoid the problems that arise when considering a very small probability, the payoff per million dollars spent on CFR will be calculated. In terms of a payoff in dollars, Table 6-1 shows that, on average, a million dollars spent on CFR provides a benefit of $430,000. However, we can also go behind the dollars to the natural units in which benefits are measured. Measuring hulls saved and non-crash benefits in dollars and measuring the human benefits in lives saved and injuries prevented, the payoff per million dollars spent on CFR is calculated, using the information in Chapter 3, as

0.10 lives saved,
0.03 injuries prevented,
$337,000 saved.

Two advantages of looking at CFR benefits in this way should be pointed out. First, the problem of imputing a value to lives and injuries is avoided. Second, if the effect of other safety programs is stated in the same form, then the "power" of a million dollars in different programs can be readily seen.

7. How sensitive are the benefit/cost ratios to the imputed value of lives and injuries? Since there is some doubt as to exactly what figures should be used as the value of a life and of an injury, the question arises as to whether using different values would have a substantial effect on the results. The answer is, "No." For example, suppose that the values used for lives and injuries are doubled to $860,000 and $128,000, respectively; also double the psychological benefits. Then the system-wide annual benefit rises from $49.881 million to $60.239 million, and the benefit/cost ratio rises from 0.43 to 0.52 Thus, a doubling of the imputed value of lives and injuries, a dramatic increase that is much larger than anyone suggests, has but a small effect on the benefit/cost ratio. The reason, as 3.6 pointed out, is that relatively few of the benefits come from preventing human loss; most of the benefits come from preventing property loss and from non-crash services. Therefore, the benefit/cost ratio shows only a slight sensitivity to changes in the imputed values of human loss.

8. <u>How sensitive are the benefit/cost ratios to the imputed value of psychological benefits?</u> In 3.2.4. it was assumed that the psychological benefit was equal to α times the benefits in lives saved and injuries prevented. To avoid understating benefits $\alpha = 1$ was assumed, i.e. the psychological benefits equal the benefits in lives saved and injuries prevented. However, no iron clad case can be made that α must be less than or equal to 1, so the question arises of how sensitive the benefit/cost ratio is to a change in α. That it is very insensitive is seen by noting that raising α to 2, a very large increase, only raises the benefit/cost ratio from 0.43 to 0.47 Again, the reason for the insensitivity is that psychological benefits represent but a small fraction of total benefits. (As a curiosity, one might ask: What value of α would make the system-wide benefit/cost ratio unity? The answer is $\alpha = 13.8$)

In summary, the ratio of CFR benefits to costs is distributed unevenly among airports of various sizes. Index C, D, and E airports, for example, account for 96.5% of total benefits and 73.5% of CFR costs. Index D and E airports account for 83.3% of benefits but only 37.0% of costs. The system-wide CFR benefit/cost ratio is well below the break-even point of unity; for

every dollar spent on CFR, only $0.43 is received in benefits. It should also be pointed out that the saving of lives and injuries, which many consider to be the primary mission of CFR, accounts for only 10.5 percent of the total benefits. One can argue about some of the specific steps followed to arrive at this figure; nevertheless, the figure is so low and so little affected by changing the assumptions on which it is based that it seems difficult to escape the conclusion that, on a dollars-and-cents basis, the CFR program does not pay for itself.

There are two ways to react to this finding. The first way is to say "The CFR program is not to be judged solely on a dollars-and-cents basis. Providing a safe environment for travelers is an essential ingredient to achieving a satisfactory quality of life; lowering the level of safety to save money would be an example of false economy." This is largely a subjective preference that is beyond argument, but it does have some objective features. For example, CFR could be compared to other safety programs to determine, for a given amount of money, how that money should be allocated among the safety programs to achieve the best attainable level of safety.

The second way to react is to say that the CFR program should be restructured so that it does pay for itself, or at least does better, on a dollars-and-cents basis. One can look into enhancing or retrenching the CFR program so as to improve its benefit/cost ratio. The purpose of this series of reports is to

address the questions of what alternatives there are for CFR policy-making and how these alternatives would affect the benefit/cost ratio. The eventual goal, then, is to provide the information that is needed in order to carry out systematic and enlightened policy-making.

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